A TEXT-BOOK

IN

GENERAL ZOÖLOGY

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ZOÖLOGY.

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INTRODUCTION

THE arrangement, presentation, and selection of the subject-matter in the present text-book have been determined by the experience gained from the labors of ten years in the class room with the grade of students for whom this work is intended. In fact, the text is simply a more orderly discussion of the same subjects in the same sequence that have been presented for ten years to successive classes in elementary zoölogy. The author, in his work with these students, has attempted to interpret, with much thought and care, the zoölogical demands of such students according to their average receptivities and practical needs rather than by any preconceived ideas of what constitutes a knowledge of zoölogy. The aim has been to create an interest in nature, beget an acquaintance with the lives, habits, and activities of animals, train the powers of observation, quicken the judgment, widen the horizon of environment, augment the capabilities for independent thinking, and inculcate an unswerving regard for the truth.

The instruction that a potential citizen receives in zoölogy must give more than a mere acquaintance with animals. If the study of this science does not accomplish the objects enumerated in the foregoing paragraph, it loses its highest value as an educational subject in the curricula of the common schools. That the study of zoölogy may fulfill its function as a subject of mental discipline and, at the same time, give to that large majority of pupils who become "ordinary citizens" an acquaintance with animals, the author has been led, from his experience in teaching, to include in a zoölogical course a goodly amount of natural history and comparative anatomy, a large share of animal ecology, economic zoölogy and physiology, a moderate amount of classification, embryology, and paleontology, something of the history of zoölogy, and, through all, a persistent presentation of the relationships of animals and of the manner in which they have been evolved. To present the foregoing divisions of the subject-matter of zoölogy in their proper relations and proportions is indeed a difficult task, and one which, at best, is open to criticism; but it is hoped that the pupils who follow the course here laid down will gain an acquaintance with animals and acquire an interest in them, and, at the same time, receive that mental discipline which they would derive from the pursuit of other studies.

Each branch of animals has been introduced by a familiar and accessible type. The discussion of the type is intended (1) to express the details of the work already supposed to have been done in the laboratory and field in an organized form, and (2) to bring out the characteristics of the branch of which the type is an example. After the different forms of the branch have been studied, their characteristics are summed up, their adaptations to environment and their economic significance are discussed, and, lastly, a clear, concise classification of the group is given. In the main, the classification accords with that given by Parker and Haswell.

The author is greatly indebted to the following men who have read and criticised parts of the manuscript, covering, in most cases, their own special fields: Dr. Gary N. Calkins and Dr. Henry F. Osborn of the American Museum of Natural History; Professors John Henry Comstock and G. D. Harris of Cornell University; Dr. T. B. Palmer, Dr. H. F. Merriam, Dr. Leonard Stejneger, Dr. Ch. Wardell Stiles, and Dr. B. W. Evermann of Washington, D.C.; Dr. J. G. Needham of Lake Forest University; Dr. C. C. Nutting of Iowa University; Professor J. S. Kingsley of Tufts College; and Mr. Edward Potts of Philadelphia. It is to be distinctly understood, however, that these men are in no way responsible for any part of the work.

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CONTENTS

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CONTENTS

ZOÖLOGY

I. THE RELATION OF ANIMALS TO MINERALS, TO PLANTS, AND TO ONE ANOTHER

Most of us are familiar in a general way with animals and plants, and with those inanimate objects we call minerals. Yet not all of us, if asked suddenly, could tell the difference between an animal and a piece of coal. It would hardly do to say that the difference lies in the ability of an animal to move from place to place while the piece of coal cannot, because some animals cannot move about any more than the coal; for example, sponges, coral polyps, etc. Moreover, there is a similarity between an animal and a piece of coal of which we had perhaps never thought. Either of them, if subjected to high heat for a sufficient length of time, will be reduced to ashes. Since the ashes to which plants and animals are reduced by heat consist of mineral matters, it is evident that these organisms are built up, partly at least, of mineral substances and to this extent are similar to coal.

This structural relation of plants and animals to minerals is much more intimate than we are accustomed to think. Plants take up mineral substances, — carbon, hydrogen, and oxygen, — form starch from them, and use that starch as food to build up vegetable tissue. Animals depend largely for their food upon the starch and cellulose manufactured and stored up by plants. Evidently, then, animals

are dependent for their very existence upon inorganic substances, and ultimately, when life is extinct, they are reduced to the same inorganic mineral materials from whence they sprung.

Notwithstanding the dependence of animals upon minerals, there is unquestionably a great difference between them. This difference resides largely in the fact that animals possess that subtle and indefinable characteristic called life, while minerals do not. On the other hand, the difference that exists between animals and minerals does not exist between animals and plants; for both of the latter possess life and hence are evidently much more closely related to each other than to minerals. In fact, so closely do animals and plants resemble each other in some cases, that it is often impossible to tell them apart. For example, look at the animal and the plant shown in Figure 1, and note the impossibility of deciding from appearances which is an animal and which is a plant. It is easy enough to tell a horse from a tree, but as we go lower in the scale of life, animals and plants become more and more alike in appearance. In fact, it is impossible to give a

FIG. 1.—*A*, Gorgonia; *C*, Fucus.

definition which will include all animals and exclude all plants, and *vice versa.* If it is said that animals move, we may reply that many plants, especially certain aquatic plants, move as freely as animals. If it is said that animals have sensibility, we may reply that plants show the same characteristic. If it is said that plants have a green coloring matter, chlorophyll, we may point to the same substance found in the bodies of certain fresh-water hydras. If it be maintained that animals take up oxygen and give off carbon dioxide, we can demonstrate that plants do precisely the same thing. There is, however, one characteristic common to all plants and all animals ; namely, the possession of life.

Whether we deal with plants or animals, then, we shall be in constant contact with life and yet probably never be able to tell exactly what it is. We can, nevertheless, find out something of the attributes and characteristics of life, and that will be our aim in the following pages.

Zoölogy. — By separating the term *zoölogy* into its parts, we find it is made up of two Greek words; namely, *zoön* — animal, and *logos* — discourse. Therefore, Zoölogy may very properly be termed a discourse on the habits, structures, development, and functions of animals.

Zoölogy, along with chemistry and physics, is one of the most extensive of all the sciences. The species of animals upon the earth are myriad in number. It is estimated that there are over a million species of insects alone, of which over three hundred thousand have actually been studied and named.

Among so vast a number of animals, many forms are met that are apparently unlike in every way. Yet each animal which we shall study or which we may find upon the earth

is like every other animal in one respect; each begins as one cell and, when mature, is made up of either one cell (Fig. 2), or a combination of many cells, together with the substances lying between, which connect the cells and hold them together. For example, one of the simplest animals, the amœba, is composed of but one cell, during its whole life. On the other hand, the whale is made up of millions of cells, together with the substances which lie between the cells and hold them in place. The one cell of the amœba performs all the functions of life, *i.e.* assimilation, reproduction, respiration, growth, etc.; while in the body of the whale, these functions are distributed among groups of cells, each group having its own special function to perform.

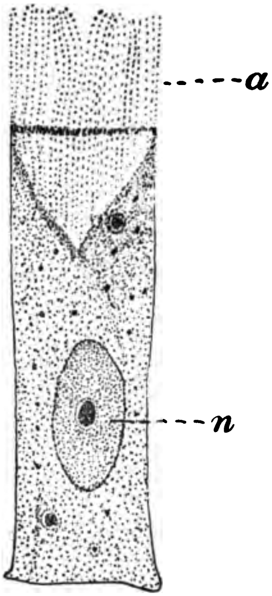

FIG. 2.—Cell of epithelial tissue; *a*, cilia; *n*, nucleus.

II. THE NATURE OF THE CELLS OF WHICH ANIMALS AND PLANTS ARE COMPOSED

A cell. — Most of us, no doubt, think of a cell as a space inclosed by walls, for example, a crayon box. In zoölogy, however, we must learn to think of a cell as something quite different from the above. In fact, a living plant or animal cell, instead of being simply a walled-in cavity, is a minute portion of semifluid substance known as protoplasm, which may or may not be inclosed by a wall.

A plant cell. — Since animal and plant cells are so much alike, and since it is easier to see plant cells, we shall examine these first. A melon vine or squash vine is covered with a multitude of small white hairs. Each of the hairs (Fig. 3, *A*), when examined under the microscope, is found to be a slender, cylindrical filament, cut up by cross walls into several distinct divisions. Each of these divisions is a cell, and each cell is bounded by a thin, transparent wall. The wall, therefore, forms a delicate sac within which is an almost colorless, granular liquid called *protoplasm.* The granules may be seen to flow along definite threads or streams (Fig. 3, *B*) in the cell by which we conclude that the protoplasm has a streaming movement. Protoplasm, in its simplest form, appears to be of the same structure throughout and somewhat resembles the white of an egg. Actually, it is a very complex substance incapable (in the living state) of chemical analysis. Usually, as seen in animals and plants, it is granular. In

every vitally active plant and animal cell, this granular liquid protoplasm is found. It is the essence of life and is a wonderful substance. It makes new flesh, blood, and bone. In fact, protoplasm does everything that is accomplished in an animal or plant.

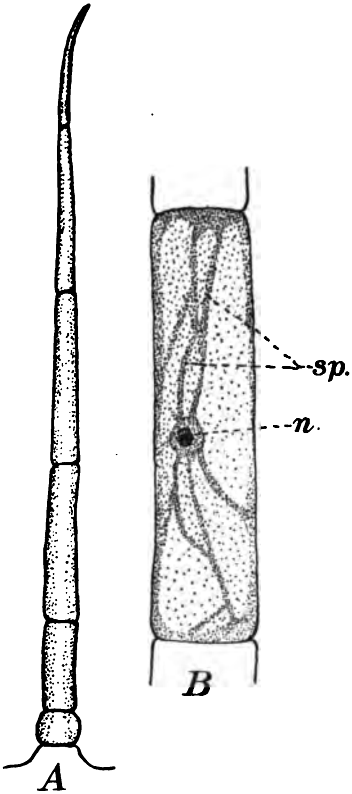

FIG. 3. — *A*, hair of melon vine, showing cells; *B*, cell much enlarged; *sp*, streams of protoplasm; *n*, nucleus.

In a living cell, the protoplasm is not of the same structure throughout; some parts of it differing greatly in structure and function from other parts. For example, a small, well-defined spot may be seen, usually along one side of the cell of the melon hair, about midway of its length. This is an organized structure of the protoplasm known as the *nucleus*. The remainder of the protoplasm in the cell is much thinner than the nucleus, has a different function to perform, and is known as *cytoplasm*. The streams of cytoplasm seem to run toward the nucleus or away from it. In other words they all seem to begin and end there. Even without other evidence this would show that the nucleus must be very important. It is plain that

if the cytoplasm is confined to the streams noted, it does not completely fill the cell. The spaces between the streams are filled with a watery fluid known as *sap*, or more properly as *cell sap*. We must not get the idea from this hair cell that all plant cells have walls about them, for they do not. Certain low plants consist, most of their lives, of a mass of free, nucleated protoplasm not confined by walls, but creeping about under decaying logs, leaves, etc.

Animal cell. — It is rather difficult to find an animal cell in which we can see the protoplasm as plainly as in the melon hair, without spending considerable time and labor in staining, sectioning, etc. But the amœba, a very simple animal found in the mud and ooze of ponds and ditches, affords an example of an animal cell that can be easily examined. It is so small and simple that one cell forms the whole animal, and hence, a study of the amœba (Fig. 4) constitutes a study of an animal cell.

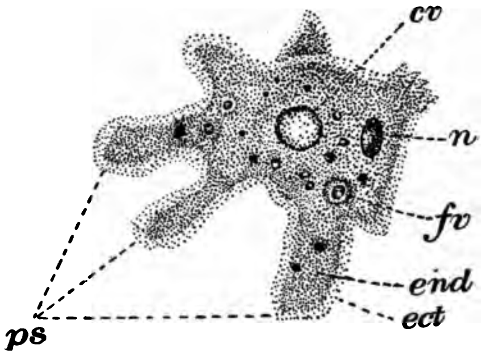

FIG. 4. — Amœba, enlarged; *cv*, contractile vacuole; *fv*, food vacuole; *n*, nucleus; *ps*, pseudopodia; *end*, endoplasm; *ect*, ectoplasm.

Where the amœba is found. — Living in the ooze and slime on the leaves and sticks in ponds, ditches, and streams, are found many kinds of microscopic animals. It is in such situations and in such company that the amœba is

found. It exists wherever such bodies of water are found, and, with care, may be obtained for study.

Structure of the body.—The body of the amœba is simply a minute mass of semiliquid, colorless protoplasm that has no permanent form because it is constantly changing in outline and shape. It may contract into a tiny ball, or it may become star-shaped, or it may stretch out and become very thin.

The protoplasm of the body is granular in structure, is not confined by a wall, and is differentiated into two distinct parts, the *nucleus* and *cytoplasm*. The nucleus is a light, roundish spot, usually somewhere near the center of the body. The remaining part of the protoplasmic mass, surrounding the nucleus and composing nearly the whole of the body, is the cytoplasm. The outer layer of the cytoplasm is somewhat denser and more transparent than the inner part. This bounding layer is called the *ectoplasm*, while the inner, granular part of the cytoplasm is called the *endoplasm*.

While the body of the amœba is active, slender, finger-like processes of the protoplasm, called *pseudopodia* (Fig. 4), slowly stream out from the body mass as though they were feelers seeking the way. These pseudopodia are often extended and withdrawn without a change in position of the body of the amœba. Not far from the nucleus is a transparent body, which, if watched long enough, will be seen to enlarge slowly and then to discharge its contents suddenly into the surrounding water. This is the *contractile vacuole*.

Method of locomotion. — The amœba has no wings or legs, yet, by watching it closely, it will be found to change its position slowly, and in this way. One side of the body begins to bulge out, and this projection soon develops into

a pseudopodium. The entire substance of the amœba then slowly streams forward upon this false foot. Another pseudopodium is put out, the streaming movement of the body takes place again, and by a succession of these movements, the amœba creeps about from place to place.

Manner of obtaining food and digestion. — Whenever a pseudopodium or any part of the body comes in contact with a desirable bit of food, the latter is gradually surrounded and ingulfed, as it were, by the body mass (Fig. 5). The ingested bit of plant is then gradually digested and

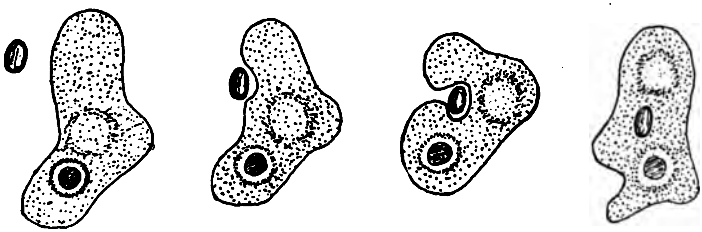

Fig. 5. — Series of diagrams showing an amœba eating a minute plant. After Verworn.

made a part of the protoplasmic mass, that is, assimilated. The amœba has no stomach or special organs of digestion, but any part of the body can take in and digest the food. The particles of ingested food are usually surrounded by a layer of water that is taken in at the same time. Generally several of these balls of food with their enveloping films of water may be seen in the body. They are called the *food vacuoles.*

Elimination of waste matters. — The solid, undigested portions of the food are thrust out of the body into the water through temporary openings in the ectoplasm. These particles of solid matter are usually eliminated from that portion of the protoplasm in the rear part of the moving animal.

The contractile vacuole is an organ of excretion and aids in getting rid of the waste matter of the body. Carbonic acid gas, water, etc., pass out directly through any part of the surface of the body into the surrounding water. In other words, the excretion of waste products may go on anywhere over the surface of the body.

How the amœba breathes. — This animal is surrounded by water containing oxygen, and this gas is taken into the body of the amœba through any part of its surface. *Vice versa,* carbonic acid gas is given off from any part of the body. It is probable that the pseudopodia are formed partly to increase the surface of the body in order to facilitate respiration.

Reproduction of the amœba. — When a new amœba is to be produced, all the pseudopodia are withdrawn and the animal lies quiet for a time. Finally, the nucleus begins to divide in half, and at the same time a constriction appears around the middle of the body. The nucleus finally divides in two; but while it is doing so, the constriction around the body becomes deeper and deeper, until finally the body is cut in two parts, each part with a half of the original nucleus (Fig. 6). Each part with its nucleus is really a new amœba. This is the simplest method of reproduction known and is called *fission.*

Sensation in the amœba. — When the amœba comes in contact with a bit of food, it reacts toward the food, and when it touches a grain of sand it moves out of the way; hence this primitive animal evidently possesses sensation.

Animal cells in general. — As a rule, animal cells have no well-defined walls about them, and for this reason the term *cell* is a misleading one. The cell has been called the unit of structure in an animal because animal tissues

are made up of an aggregation of cells, — nucleated masses of protoplasm. In the many-celled animals, the cells are of various shapes and have various functions to perform. Some cells are cylindrical, some spherical, some flat and scalelike, some like a cube, some like a pyramid, and some

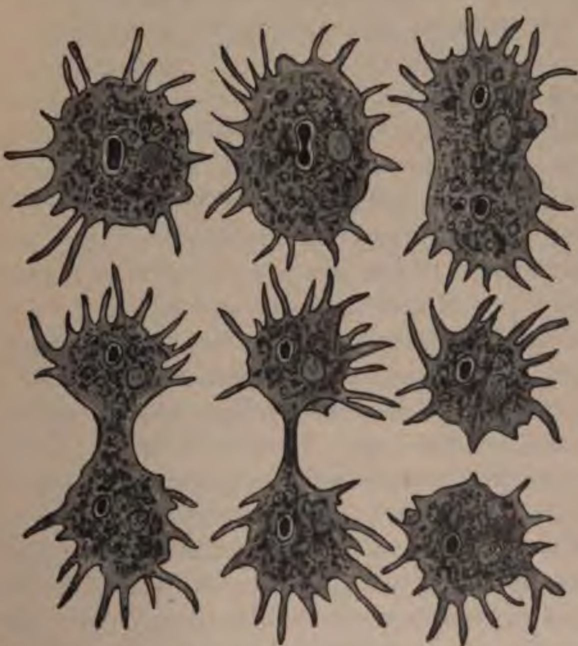

FIG. 6. — Stages in the division of an amœba. After Schultze.

greatly elongated and spindle-shaped. Some cells perform the function of motion, *e.g.* those of the muscles; others carry impulses, *e.g.* the nerve cells; others secrete digestive fluids, *e.g.* those of the salivary glands. To sum up, then, *a living animal cell may be defined as a mass of living protoplasm with a nucleus and usually without a definite wall.*

III. THE GROWTH OF ANIMALS AND THE FUNCTIONS OF THEIR ORGANS

Spontaneous generation. — A jar of water containing a handful of hay will literally swarm with microscopic animals at the end of a week if left standing in a warm room. Apparently these animals arise spontaneously or spring, as it were, from nothing in the way of animal life. Formerly zoölogists called this sudden appearance of so many active animals a case of *spontaneous generation.*

Ancient zoölogists held that flies were spontaneously generated in the flesh of dead animals; and that frogs, toads, and reptiles might be produced from the moist, slimy earth of rivers and seas. We now know that flies, frogs, and toads develop from eggs deposited in favorable places by the female parents. And Pasteur has shown that when infusions of hay are boiled and hermetically sealed they may be kept indefinitely without a trace of animal life. Moreover, it has been demonstrated that many plants and animals produce great numbers of tiny cells known as *spores* or *germs,* and that these fall upon grass and in the water. Therefore, when these two substances are put together in a suitable temperature, the spores germinate and produce swarms of minute animals; but if the spores are killed by boiling, no animals appear in the infusion. It would seem, then, that there is no such thing as spontaneous generation, but that all life comes from some life that went before.

How animals begin. — Every animal,[1] no matter how large or how small, begins as one cell, and in this all animals are alike.

This one cell, in the majority of animals, is known as the egg cell, or ovum. The egg cell itself is very small; but in many cases, especially in the case of those animals that lay eggs, the egg cell is inclosed in an enveloping membrane, which in turn may be inclosed in a hard, thick shell. The membrane and shell have within them, in addition to the egg cell, a considerable quantity of food, known as the yolk. The egg cell, with its food yolk and membrane and shell (when the latter is present), constitutes what we know as an egg. Eggs vary greatly in size, owing to the difference in the quantity of food yolk they contain. For example, a hen's egg is much larger than the egg of a pond snail, because the former contains much more food than the latter.

The majority of animals lay eggs, sometimes on land (*e.g.* bird, turtle, etc.), sometimes in water (*e.g.* fish, frog, etc.), but sometimes the eggs are retained in the body of the parent animal. Moreover, most of the mammals retain the egg cell and allow it to develop into an embryonic animal within the body of the mother. But whether the egg cell is deposited outside of the body of the mother, or whether it is retained within the body of the mother for a certain period, it undergoes similar changes in its development into an adult animal.

How cells increase in number. — We have learned in the foregoing paragraph that all animals begin as one cell. Yet the animals with which we are most familiar consist of

[1] This may not hold strictly true in case of the hydra when it reproduces by budding.

myriads of cells. Consequently, the one cell with which they began has been increased in number many times. The manner in which the cells in an animal's body increase in number is important and interesting.

Perhaps the simplest manner in which cells may increase in number is shown by the amœba. We have seen that a new amœba is formed simply by division, or fission of the body. In this process of the formation of new cells, no remarkable changes occur. But in the case of higher animals, when a cell divides, the nucleus usually passes through a remarkable and complicated series of changes to which the term *karyokinesis*, or *mitosis*, is applied (Fig. 7). A spindle-shaped body with a starlike organ at each end forms in the cell. The substance of the nucleus, which has meanwhile been transformed to rodlike bodies called *chromosomes*, is then drawn to the spindle. Finally, each of the chromosomes splits in two equal parts, and one half of the resultant

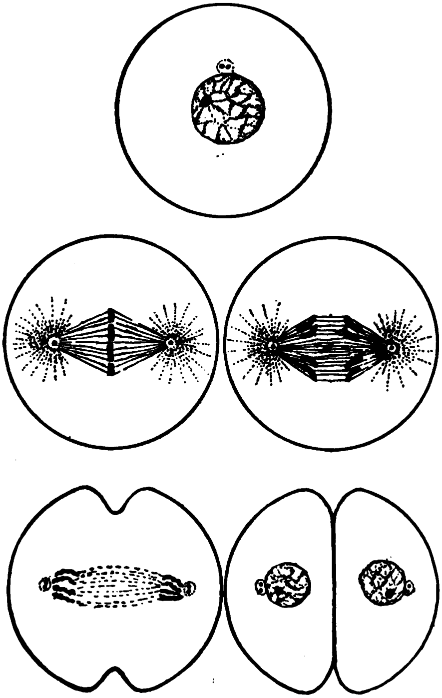

Fig. 7.—Stages of cell division by mitosis. Diagrammatic.

number then passes to one end of the spindle and the other half to the opposite end of the spindle. The spindle then contracts in the middle and eventually breaks in two, as it were, and after a few more changes two complete new nuclei are formed, after which the body of the cell divides in two, thus forming two new cells. Figure 7 shows these changes in detail.

Growth of animals. — Growth takes place in an animal mainly by an increase in the number and size of the cells. This means, in general, that a tiny kitten does not possess as many cells as a large kitten and that a large kitten does not possess as many cells as a full-grown cat.

Before the egg cell, from which most animals originate, begins to form mother cells, it must be fertilized by the male sperm cell. After fertilization it is known as the fertilized egg cell, or *oösperm*. The oösperm may begin at once to divide and start the development of the animal. The character of the division varies in different cases, but, in general, the oösperm, or a part of it, divides into two cells, these into four, these into eight, these into sixteen, and so on until a globular ball of similar cells is formed. At this point in the development of the embryo, a change occurs and the cells cease dividing so regularly in multiples of two. They now begin to differ from each other in shape, size, and function, and some of them go to form skin, others to make bone, others to build up muscles, and so on until every part of the animal is formed. While this activity among the cells is going on, food is needed to furnish energy and materials out of which the cells may be built. Even after the animal is formed, a constant supply of food is demanded for building new cells to take the places of those worn out and cast off.

Organs of animals. — The body of an ox is made up of many different parts, or organs, and each organ has a certain function, or work, to perform. For example, the lungs perform the function of purifying the blood, the legs are for locomotion, the ears for hearing, and the eyes for seeing. We may define an organ, then, as a part of an animal that has some definite function to perform.

The relation of function to structure. — The leg of a duck performs the double function of walking and swimming.

Fig. 8. — Foot of duck, blue jay, mole, and seal, respectively, showing adaptation to function.

It is accordingly provided with joints, muscles, toes, and a web between the toes. The feet of a blue jay are fitted for perching. The limbs of a seal are fashioned for swimming and the feet of a mole for digging (Fig. 8). The teeth of a dog are constructed for tearing flesh, but the teeth of an elephant are suited to grinding vegetable material. From these examples, it will be seen that the structure of an organ is suited to the work, or function, it has to perform. The higher we go in the scale of animal life, the more complex becomes the function and structure of organs. This is shown by the fact that a bird's wings are much more

complicated, both in structure and in the work that they do, than the fore legs of a grasshopper.

The animal as a machine. — We have seen that the body of an animal is made up of many parts, or organs, each with its own particular work, or function, to perform. With respect to its structure, then, an animal's body is very similar to a machine. In truth, the animal body may be considered a machine, in which each part performs a special kind of work, and although dependent on the other parts, contributes its share to the labor of the machine as a whole. For example, a locomotive has a fire box into which the fuel is thrown that is to produce the energy to run the engine. Similarly, the animal body has an alimentary canal which receives and assimilates the food from which energy is derived. The locomotive is provided with a smokestack and exhaust valves to conduct away the waste materials, while the lungs, skin, and kidneys act in a similar capacity for the body. The engine has its steam cylinders in which the transformed energy of the fuel, through the medium of steam, sets up motion. In a corresponding manner, the animal body is furnished with muscles, through which the transformed energy of the food expresses itself in the form of motion. Moreover, the engine must be supplied with fuel and water to keep it running; and similarly, the animal body demands food and water to maintain its activity. If the steam cylinders of the engine wear out, the locomotive becomes useless. If the kidneys of the animal body become incurably diseased, the body dies.

Of course, it must be remembered that the animal body has that subtle and indefinable characteristic we call life which the locomotive has not; and this makes a very great and real difference between them.

IV. THE CLASSIFICATION OF ANIMALS

In most libraries, the books are arranged on the shelves in a certain order. One class of books occupies a certain shelf or shelves, and another class, other shelves. Or, as we say, they are classified and arranged. For example, all books of history are put into a group by themselves, books of fiction into a group by themselves, books of biography by themselves, and so on through the list.

Now in much the same way animals are gathered together in groups. Certain ones much alike are put into one group, certain others much alike but differing from those in the first group are put into another group, and so on through the whole animal kingdom. Like the books in the library, animals are arranged in groups for convenience of study. More than this, however, animals are gathered into groups that we may get a better understanding of their relationships to each other. In our study of animals we shall find that a relationship,[1] or kinship, exists throughout the animal kingdom from the amœba to man. Each animal bears a certain relation to the remaining members of the kingdom, although this relation is much closer with some animals than it is with others. The object of zoölogical classification is to express the relation of one animal to the others in the kingdom and to determine what place it occupies in the great assemblage of animals. The classi-

[1] By this we do not mean that the members of the animal kingdom form a serial arrangement, but rather such an arrangement as is shown by the diagram in Figure 9.

fication of animals is a most fascinating study and one that trains the mind, develops the powers of observation and discrimination, and strengthens the judgment.

If we were to attempt to classify animals according to color, we should have some buffaloes, some cats, some monkeys, and some birds in one group. Plainly this would be a poor classification and of no use. The groups into which animals are gathered are based upon permanent anatomical structures or fixed characters rather than upon superficial resemblances. These groups are of different rank and vary greatly in size, for the groups of high rank contain or include many more animals than those of low rank.

Species. — The smallest and lowest group which is usually taken into consideration is that known as *species*. For example, we know that all of the common house cats have claws alike, possess the same kind of eyes, make a similar purring noise, and are of about the same size when full grown. Consequently, we consider them the *same kind*, or *species* of animals. Moreover, all house cats, of whatever size or color, belong to the same species. Furthermore, we know that kittens will grow and become like their parents. Therefore, we may, in general, consider a species as a collection of animals, the individuals of which possess several similar, fixed, and permanent characters and the offspring of which possess the same unchanging characteristics.

Genus. — If a cat be compared with a tiger, many points of resemblance between the two animals will be noted. Both have long, slender, agile bodies, the same noiseless tread, much the same kind of mouth with long bristles on each side of the upper lip, and similar eyes. On the other

hand, the tiger is much larger and stronger, its body is differently marked, and the fur is more compact and glossy. It is evident that these two animals are of a different kind, or species, yet are very closely connected. In fact, they are so closely related that they are placed in one and the same group known as a *genus*. Again, the lion and the leopard are two distinct species of animals, but so closely related to each other and to the tiger and domestic cat that they are included in the same genus. A genus usually includes several closely related species, but it may consist of one species only.

How animals are named. — The scientific name of each animal consists of two words taken from the Latin or Greek languages, usually the former. The first word of the name is the name of the genus to which the animal belongs. The second word is the name of the species to which the animal belongs. For example, the scientific name of the domestic cat is *Felis domestica*, in which *Felis* indicates the genus and *domestica* the species to which the cat belongs. In like manner the lion is known as *Felis leo*, the tiger as *Felis tigris*, and the leopard as *Felis pardus*. This method of naming animals tends to insure uniformity, because every zoölogist, no matter of what nationality, in writing of a particular animal, uses the same name, thereby avoiding confusion and, at the same time, indicating the precise animal under discussion.

Family. — If a wild cat and Canada lynx were compared with a tiger and a house cat, we should find that they possessed similar eyes, walked in a similar manner, and had similar mouths with whiskers on the upper lips. It is evident that they are all catlike animals. On the other hand, we should find that the lynx and wild cat differed

from the house cat and tiger by possessing triangular ears, short tails, and comparatively long legs. Moreover, the lynx has a pencil, or tuft of hairs on each ear, and occasionally a wild cat is found with ears bearing like tufts. Plainly, the lynx and wild cat differ enough from the tiger and domestic cat to be considered different species. In fact, the differences between them are so great that the lynx and wild cat are placed in a different genus from that to which the tiger and house cat belong. Therefore, the lynx and wild cat represent one genus, while the cat and tiger represent another and different genus. But, since they are all so catlike, they, together with the leopard, lion, panther, jaguar, etc., are placed in a group known as a *family* (cat family). In like manner, the dogs, wolves, foxes, etc., form the dog family.

Order. — To go further, we know that the house cat, tiger, lion, lynx, dog, fox, wolf, bear, and raccoon resemble one another in possessing teeth fitted for tearing and eating flesh, which forms all or a greater part of their food. Therefore, all of these animals are assembled together in one large group known as an *order* (Carnivora).

Class. — Again, the bears, dogs, cats, tigers, lions, wolves, etc., resemble buffaloes, elephants, deer, rats, mice, etc., in possessing milk glands and suckling their young. Therefore, all of these animals are gathered together in a group known as a *class* (Mammals).

Branch. — Finally, all of the foregoing animals, together with birds, fishes, reptiles, etc., possess, at some time of their life, a semicartilaginous cord that runs along the back between the nervous system and the alimentary canal, known as the *notochord.* Therefore they are all placed in one group known as a *branch* (Chordata).

To put all this in a simpler form, we would say that individuals are grouped together to form species, species to form a genus, genera to form a family, families to form an order, orders to form a class, and classes to form a branch.

The following table illustrates the classification of the domestic cat:

Kingdom. All animals.
Branch. Animals with a notochord.
Class. Animals having milk glands and suckling their young.
Order. Animals tearing and eating flesh.
Family. Animals with sharp retractile claws.
Genus. Cat, lion, tiger, and leopard.
Species. Domestic cat.

Fig. 9. — Diagram illustrating classification.

As we said before, in our study of animals we shall find a kinship existing throughout the animal kingdom. More than that, we shall also find a step-by-step progress from the lowest to the highest. This very important point will be brought out more clearly farther along, but can best be represented here by a tree diagram. By the latest authority, the animal kingdom is divided into twelve great branches; but for the sake of simplicity we have grouped four of these into one — the worms — in the diagram (Fig. 9).

V. AMŒBA, VORTICELLA, PARAMECIUM

Branch I. — Protozoa (*protos*, first; *zoön*, animal)

All of the protozoans are very simple in structure, for all are single-celled animals. Frequently, the cell composing the body of a protozoan possesses a wall, but sometimes it does not. One point in regard to these animals is of especial interest; namely, that all the processes of life are carried on by this one cell. Every member of this group has the power of motion, digestion, assimilation, and reproduction, all of which functions are necessarily performed by the one cell. They are mostly microscopic and are widely distributed. Some live in salt water, and some live in fresh water.

An Example of the Branch — the Amœba

We have already fully discussed the amœba in a former chapter, and shall, therefore, pass directly to a consideration of other members of the Protozoa.

Protozoans with shells. — The amœba has no shell, not even a cell wall for protection. But there are many protozoans that possess shells. Some of the shells are composed of carbonate of lime, some are made from silica, while some are formed from grains of sand cemented together. Most of the shelled protozoans are marine; a few are found in fresh water. The marine species are found at various depths in the sea. Some of them live at or near the surface of the ocean, and others live at great depths.

One great group, or order, called Foraminifera, are nearly all marine. The shells of these animals, in most species composed of lime carbonate, have either one or two large terminal openings or are perforated with many minute openings. Through these minute holes there project long, delicate protoplasmic threads, the pseudopodia. These fine pseudopodia often unite to form a network about the shell (Fig. 10). The shells of many Foraminifera are rather complicated in structure and present a variety of shapes and patterns. Many of them are divided into chambers. Nevertheless, they are one-celled animals, because all the chambers are connected with one another so that the protoplasm constitutes one body mass, or cell.

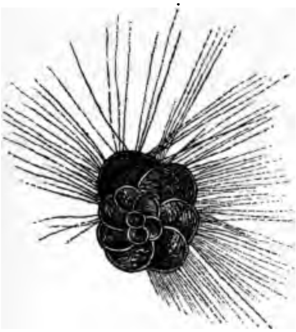

FIG. 10. — One of the Foraminifera with streams of protoplasm (pseudopodia) projecting through openings in the shell. After Schultze.

The marine Protozoa are myriad in number of individuals. One species especially, called Globigerina, lives in such immense numbers in the sea, usually near the surface of the water, that the dead shells, which are constantly falling downward, form a mud, or ooze, in some cases of considerable thickness, on the bottom of the ocean. The shells of this animal are microscopic in size, and composed of lime carbonate. In England and France, great beds of white chalk exist to-day which, when examined under a microscope, prove to be composed almost wholly of the shells of globigerina and other minute Foraminifera.

Slipper animalcule, or paramecium. — Unlike the amœba, this protozoan has a definite shape. It is microscopic, but

just on the border of vision, and is shaped somewhat like a slipper. It may be obtained in abundance from an infusion of hay.

The body of the slipper animalcule is inclosed with a thin cuticle which retains the shape of the body. All over the body are longitudinal rows of minute, eyelashlike appendages, called *cilia*. The paramecium moves swiftly through the water by means of the rapid vibrations of cilia. On account of their rapid motion, the cilia are difficult to see in a living specimen.

On one side of the body is a long, slightly twisted groove (Fig. 11), known as the *oral groove,* that extends into the

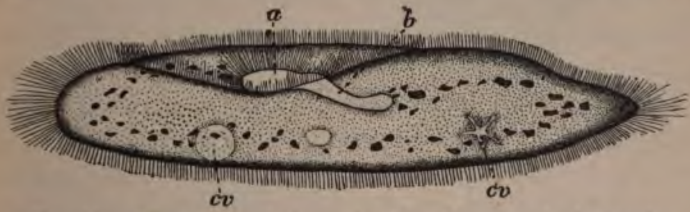

FIG. 11.—Slipper animalcule much enlarged: *a*, mouth; *b*, throat; *cv*, contractile vesicles.

body and finally becomes a tube. At the inner end of this tube is the mouth. The paramecium has two contractile vacuoles, one near each end of the body. Two nuclei are present, but difficult to see.

Paramecia reproduce by fission in much the same manner as the amœba. There comes a time, however, when it seems that the process of fission cannot be repeated again until quite a different process has taken place. This process is known as conjugation and may be considered a rejuvenating process. Two individuals come together, and an actual interchange of a part of the substance of the

nucleus of each animal takes place. After conjugation occurs they reproduce rapidly by fission as before.

Bell animalcule, or vorticella. — These animals occur in infusions of hay and in bodies of fresh water attached to leaves, sticks, and pond scums. The body is shaped like an inverted bell and has a long, slender stalk by which it is fastened to objects in the water. The body is invested with a transparent cuticle, but the cilia are confined to the edges of the bell and vestibule. On the margin of the bell is a deep oral groove, the *vestibule*, that extends downward toward the center of the body (Fig. 12) and ends with the mouth. The long, slender stem is composed of an outer transparent sheath and an inner muscular rod, or axis. In nature, these little animals are constantly pushing out and darting back to their places of support by means of the uncoiling and coiling of the slender stems. As one darts back, the edges of the bell become inverted and turned inward so far that the body assumes a globular shape. As it slowly pushes

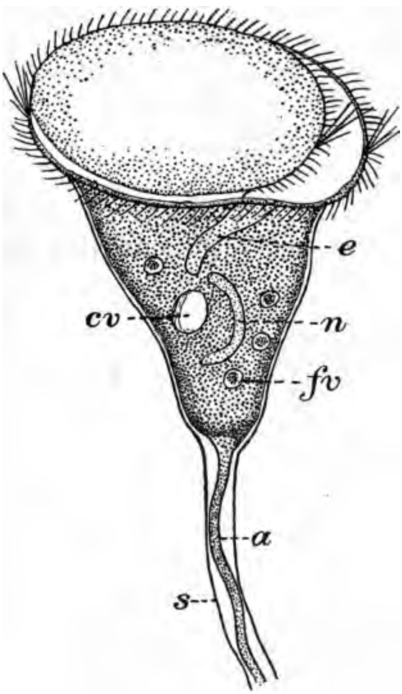

Fig. 12. — Bell animalcule, or vorticella: *e*, gullet; *n*, nucleus; *cv*, contractile vacuole; *a*, axis; *s*, sheath; *fv*, food vacuole.

out again, the edges turn outward and the body expands until it gradually assumes its former shape.

Vorticellæ reproduce by fission, one of the resultant forms swimming away and developing a stalk for attachment. At times they conjugate, while some individuals may become encysted and divide up into *spores* or *germs* which finally escape from the cyst and develop into new individuals.

General characteristics of the Protozoa. — With the amœba, we started among the most primitive animals. It may seem strange that the oldest animals are the simplest, but it is true. It is probably due to the fact that these animals have always lived in the water, and the water is probably not very different to-day from what it was ages ago. Hence there has been nothing to bring about change in these animals, and they have remained much the same.

Again, bear in mind that we have been dealing entirely with one-celled animals. Yet they can do, in a simple, primitive way, much that we can do. They can all move; some slowly, by crawling, as the amœba; some faster, by thousands of cilia, as the paramecium; while others, like the vorticella, are attached, yet possess distinct and remarkable movement, within a certain limit. All collect food and assimilate it and grow as any other animal. Each one breathes, of course in a primitive manner; but, nevertheless, oxygen is taken in, and carbonic acid given off as regularly as among the higher animals.

If we jar the slide on which the vorticella is placed, the tiny animal will suddenly roll into a ball and dart back to its place of support. We have already seen how the amœba reacts toward food and avoids a grain of sand. Paramecia are sensitive to an electrical current. Hence we see that

all of these simple animals have sensation, because they respond to irritation.

Another thing is important to note in our study of the foregoing animals. Beginning with the amœba, we went steadily upward to higher and more complex forms. The amœba had no wall, all the others had. The amœba had no mouth, all the others had. The amœba moved slowly and in a very primitive way, the paramecium faster, while the vorticella had the most complex movement of all. Moreover, it will be recalled that the amœba moved in any direction, and that almost any part of the body seemed capable of bringing about this movement. The amœba has no sharply defined anterior and posterior ends, and no right and left sides. The paramecium has a posterior and anterior end and moves principally in one direction with a definite part of its structure foremost.

Economic importance of the Protozoa. — Although the protozoans are microscopic in size, some of them exercise a very profound influence upon the life relations of man. Occasionally certain species become so numerous in drinking water that the water is rendered unfit for use. A species of amœba is known to sometimes occur in the intestinal tract of man and has been thought, by some, to be the cause of dysentery.

Texas fever, so universally present among the cattle of the Southern states, is caused by one of these microscopic animals. This organism is injected into the blood of an animal and carried from one animal to another by the common cattle tick. Whenever cattle south of what is known as the *tick line* come in contact with cattle north of that line, the latter are inoculated by the tick and usually die.

It has been demonstrated that a certain protozoan, injected into the blood of man by mosquitoes, causes the disease, malaria. The parasite lives within the red blood corpuscles, destroying great numbers of them and finally inducing chills and fever, and in many cases causing death. The life history of the malarial parasite is interesting and complex. Part of its life is spent in the body of certain species of mosquitoes and part in the human blood. That is, the full development of the malarial parasite cannot take place in the human blood, but a secondary host, the mosquito, is necessary in order that the complete life history of the parasite may be undergone.

CLASSIFICATION OF THE PROTOZOA

BRANCH I — Protozoa.
- *Class* — Sarcodina.
  - Order — Amœbida.
    - Types of Order:
      - *Amœba proteus* — Amœba.
      - *Globigerina bulloides* — Globigerina.
- *Class* — Infusoria.
  - Order — Holotrichida.
    - Type of Order:
      - *Paramecium aurelia* — Slipper animalcule.
  - Order — Heterotrichida.
    - Type of Order:
      - *Stentor polymorphus* — Stentor.
  - Order — Peritrichida.
    - Type of Order:
      - *Vorticella nebulifera* — Bell animalcule.
- *Class* — Sporozoa.
  - Order — Hæmosporidiida.
    - Type of Order:
      - *Plasmodium malariæ* — Malarial parasite.

VI. SPONGES

Branch II. — Porifera (*poræ*, pores; *ferens*, bearing)

All sponges live in water, either fresh or salt. The fresh-water sponges may be found in rivers, lakes, ponds, etc., probably in every country in the world. The marine sponges are very widely distributed in the sea and occur at nearly all depths, from the shallow to the very deep parts of the ocean. In some parts of the sea they are exceedingly abundant. They are of multitudinous forms, individuals of the same species varying greatly in shape. Some are flat, some are globular, some are treelike in shape, others are vaselike in form, while some are cylindrical. This variation in shape is due largely to the fact that they are easily modified by surrounding conditions. A change in current or a change in the character or shape of the sea bottom will almost surely bring about a change in the shape of these animals. When the young marine sponges are first hatched from the egg, they are, for a time, free, and they can move about through the water. They soon become attached and for the rest of their lives remain stationary. Hence sponges may be said to be fixed animals.

Structure of a simple sponge. — The simplest sponge that we know anything about is vase-shaped, with the lower end contracted into a sort of stalk by which the animal is attached. Generally speaking, the body is a hollow cylinder, closed at the lower end but open at the opposite,

or free end. Scattered over the surface of the sponge are small rounded apertures, which are the openings of short pores, that pass directly through the body walls into the central or body cavity. These pores are called the inhalent pores because the water flows through them into the body cavity. From thence the water passes out through the large opening, or *osculum* — exhalent pore — at the free end of the sponge. Thus there is a continuous circulation of water through the body of this simple animal.

The body wall consists of three distinct layers, an outer layer, consisting of flat cells closely joined to each other and covering the outside of the body; an inner layer, of much thicker cells, lining the body cavity; and between these two, a layer of whitish, soft, gelatinous substance with cells of various shapes imbedded in it. Each of the cells composing the inner layer of tissue has a long, lashlike appendage, called a *flagellum*, that projects from the end of the cell into the large body cavity. These flagella are constantly waving, or lashing, and in this way they maintain currents of water that bring bits of organic food to the animal. All three layers of the body are soft, especially the middle one, and if the sponge had nothing rigid to support it, the body would collapse. Imbedded in the middle, gelatinous layer, are slender, glassy, needlelike bodies composed of lime carbonate, and known as *spicules*. These constitute the skeleton, as it were, and support the body.

A More Complex Example of the Branch — the Simple Sponge, Grantia

Distribution. — Grantia is a simple sponge found along the Atlantic and Pacific coasts. It occurs in small groups, attached to submerged rocks or other objects below low-

water mark. It is easily obtainable for study, while the simpler sponge is not.

External features. — The body is about one half an inch in length, cylindrical in shape, and fixed by one end, while the opposite end is furnished with a small opening, the *excurrent opening*, or the *osculum* (Fig. 13). The osculum is surrounded by a collar of long, white, calcareous, needlelike spines called *spicules*.

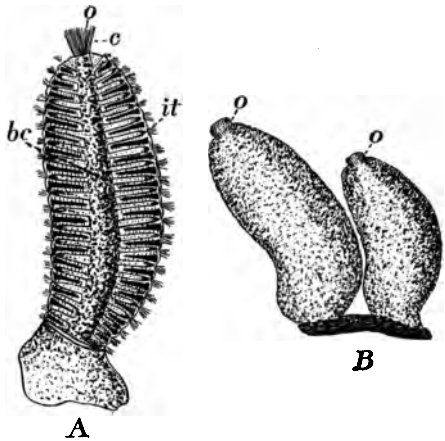

FIG. 13. — Sponge (*Grantia*): *A*, an individual split lengthwise showing body cavity (*bc*), inhalent pore (*it*), osculum (*o*), circle of spicules (*c*); *B*, two individuals attached to a stick.

Structure of the body. — The body is a hollow cylinder with rather thick walls. The large central cavity, or *cloaca*, extends throughout the length of the body and opens outward through the osculum. The body walls are perforated with two sets of parallel canals that run at right angles to the cloaca. One set, the *inhalent canals*, runs from the outside of the body almost to the cloaca and ends blindly. The other set, the *radial canals*, begins at the cloaca and runs parallel with the inhalent canals, but ends blindly just before reaching the outside of the body. These canals run side by side and communicate with each other by minute pores through their adjoining walls. The water enters the inhalent canals through the incurrent pores, the mouths by

which these canals open outward, passes through fine openings in the walls of the former directly into the radial canals, from which it escapes into the cloaca and thence outward through the osculum.

Body walls. — The body walls of Grantia are much thicker than those of the simple sponge, and the pores are longer. There are three layers of tissue similar to those of the simple sponge, already described.

The inner layer, lining the radial canals, has its cells peculiarly modified in structure, and they are known as *collar cells*. Moreover, each collar cell possesses a long vibratile flagellum. All of these flagella are constantly waving with lashlike vibrations and thus maintain currents of water through the canals.

Skeleton. — Like the simple sponge, Grantia has its body supported by a mass of interlaced spicules, composed of lime carbonate (Fig. 14). Two kinds of spicules are always to be found, — triradiate and needle-shaped. The triradiate spicules are interlaced and interwoven in the middle layer of the body walls so that they form a skeleton or supporting framework. The needle-shaped spicules are found projecting through the outer layer of cells all over the body.

Fig. 14. — Sponge spicules.

Method of feeding. — This sponge feeds upon microscopic bits of plant and animal organisms, floating in the

sea. The currents of water entering the incurrent pores are laden with these minute organisms, which are taken up by the collar cells of the radial canals and digested. There are no special organs of digestion, but each of these cells gathers and digests its own food.

Method of breathing and excretion. — The same currents of water that bring food also carry fresh oxygen, which is given up to the cells as the water passes over them. At the same time, the cells give off carbonic acid gas, which is carried outward by the water, and thus the sponge breathes.

The particles of undigested food are carried out through the osculum by the currents of water. Whatever waste substances the cells excrete are got rid of in the same way.

Reproduction and life history. — Grantia reproduces by budding. That is, a bud forms on the external surface of the body, which gradually increases in size and grows into a new sponge individual. In the case of Grantia these bud sponges break away from the parent, become attached, and pass a solitary existence. In some sponges they remain attached to the parents and thus there comes to be formed a large colony of individuals.

Grantia also reproduces in a sexual manner, although "specialized reproductive organs are not present. The sexual elements will be found in the form of large spherical bodies in the wall of the sponge. Fertilization takes place here, and development begins, and the young embryos escape into the sea water through the canals. For a while the embryo is a free-swimming animal, but it finally fastens itself to a rock and develops into the adult sponge."

Structure of other sponges. — All sponges may be said to have the three layers of tissue found in the simple sponges; but, in other respects, the structure of the body in the

higher sponges is much more complicated. In the higher sponges there is no general body cavity, but the whole sponge mass is full of large tubes, each with its osculum. Moreover, there are innumerable inhalent pores leading into special pockets, or chambers in which the flagellated cells are situated. Recall that the flagellated cells in the very simple sponge are situated in the general body cavity. The chambers containing the cells with flagella communicate, by small canals, with the large tubes. Thus there is provision for the same circulation of water as in the simple sponges. Sponges are of various colors. They may be red, orange, blue, purple, green, and gray.

Fresh-water sponges. — Most of the sponges are found in the sea, but a few live in fresh water. The fresh-water species are very widely distributed in lakes, ponds, rivers, etc., hence they may be found in many localities. Reproduction is brought about by a budding process. A spherical mass of cells, surrounded by a hard siliceous case and known as a *gemmule*, is formed within the body of the parent sponge. In the autumn this bud, or gemmule, is set free in the water by the decaying of that part of the body in which the gemmule lies. The gemmule, after being set free, settles to the bottom of the water, where it passes the winter. With the change in temperature in the spring, the cells within the case escape through the natural hilum, or orifice of the gemmule, begin growing, and soon develop into a mature sponge. The fresh-water sponges belong to the family Spongillidæ.

Skeletons of sponges. — Some sponges have no skeleton. In those sponges in which a skeleton exists, it is formed by the cells of the middle layer and may consist of different substances. In some, the skeleton is formed from spicules

composed of silica; in others, the skeleton is formed from spicules composed of lime carbonate; while in others, it is formed from fine, flexible fibers of a substance called *spongin*, which is allied to silk in chemical composition. Those sponges which have a skeleton composed of silica are harsh and unfit for domestic purposes. Those with skeletons of spongin are soft and are used for various domestic purposes. See Figure 14 for spicules of various shapes.

Siliceous sponges. — The most beautiful of marine sponges have skeletons composed of silica. The spicules are like spun glass, and in the sponge, known as the Venus's basket, they are arranged so uniformly that the skeleton resembles a piece of fine lacework (Fig. 15, *E*). This sponge is found growing near the Philippines in about ten fathoms of water.

FIG. 15. — *E*, Venus's basket sponge; *H*, glass-rope sponge.

Another one, sometimes called the glass-rope sponge (Fig. 15, *H*), has a long stem composed of the long, white, glassy spicules twisted together. The sponge body grows on the upper end of this stem, while the lower end of the stem is anchored in the mud.

Sponges of commerce. — The sponges that we see in the drug stores are nothing but the interlaced masses of soft, flexible, spongin fibers that compose the skeletons. Our best sponges come from the Mediterranean, the next best from the Red Sea, and a poorer quality from the Bahamas, West Indies, Key West, and west coast of Florida. In gathering them for market, they are pulled from the rocks with pronged hooks attached to poles whose length is at least as great as the water is deep. In deep waters, divers go down and gather them off the rocks. After being collected they are either exposed to the air until the soft parts decay, or they are thrown into kraals, or cribs, near low-water mark, and left where the tides wash through them, until the fleshy parts pass away. They are then bleached, dried, and sent to market.

Relation of sponges to other animals and to their environment. — Sponges were originally thought to be colonial Protozoa, but it has now been determined that they produce eggs and that these eggs, during development, first divide into two cells, these into four, these into eight, these into sixteen, and from these the mature sponge finally develops. Such a mode of development certainly excludes them from the one-celled animals. At the same time, the sponges are the simplest of the many-celled animals. The one cell of the Protozoa does everything, but in the sponges some cells gather food, other cells perform reproduction, while others digest food. These different cells, each dependent upon the other, are joined together to form an organized but simple body in comparison with other metazoans.

It is evident that the sponges could not live on land because they are fixed and food must be brought to them, and

water is the most suitable agent for carrying food. The sponge is furnished with cells bearing flagella which, by their movements, maintain currents of water laden with food.

Economic importance of the sponges. — A few sponges have formed the habit of boring into limestone rock and into the shells of certain mollusks, but the destructiveness of these few is probably not great. On the other hand, the commercial trade in sponges is large. The sponge fisheries in the Mediterranean Sea give employment to thousands of people, and the receipts from sponges sent to foreign markets amount to thousands of dollars annually. The value of the sponges handled in Trieste, alone, in one year, amounts to nearly two hundred thousand dollars, and the demand for sponges is continually increasing. Moreover, there are the sponges from the Bahamas, Red Sea, and West Indies that must be taken into account in any reliable estimate of the economic value of sponges.

CLASSIFICATION OF THE SPONGES

BRANCH II — Porifera.
- *Class* — Porifera.
  - *Ascetta primordialis* — Simple sponge.
  - *Grantia species* — Simple sponge.
  - *Euplectella aspergillum* — Venus's basket.
  - *Hyalonema species* — Glass-rope sponge.

VII. HYDRÆ, JELLYFISHES, SEA ANEMONES, CORAL POLYPS

Branch III. — Cœlenterata (*koilos*, hollow; *enteron*, intestine)

The Cœlenterata, which include the corals, jellyfishes, sea anemones, etc., occur, without exception, in the water, and the majority of them are found in the sea. In general they are much more complex in structure and development than the sponges, but resemble the sponges in several respects, namely, in the tendency to reproduce by budding and form colonies; in their fixed mode of life; and in the possession of one body cavity. Perhaps the corals are the most familiar examples of this group, but there are many other little-known members, the characters of which will be better understood after the study of a few leading types.

An Example of the Branch — the Fresh-water Hydra

Where the hydra lives. — The fresh-water hydra lives in ponds, pools, ditches, and streams where there is an abundance of water plants, such as duckweed, algæ (pond scum), etc. There are two species of hydræ that are common, the green hydra and the brown hydra.

External features. — The hydra has a long, cylindrical body attached to some part of a submerged water plant or other object by the posterior end, while the anterior end sways free in the water. The mouth is situated at the

anterior end and is surrounded by five to eight slender appendages, the tentacles. These are often as long as the body (Fig. 16).

Movements and locomotion of the hydra. — Although the hydra, for the major part of its time, remains fixed by its posterior end to some submerged object, yet, even in this position it is capable of considerable movement. For example, the body can be contracted until it appears like a tiny ball or extended until it reaches half an inch in length. Likewise, the tentacles may be contracted until they appear as small knobs about the mouth or extended until they become very slender and as long as the body. Moreover, the body and tentacles sway about through the water in search of food.

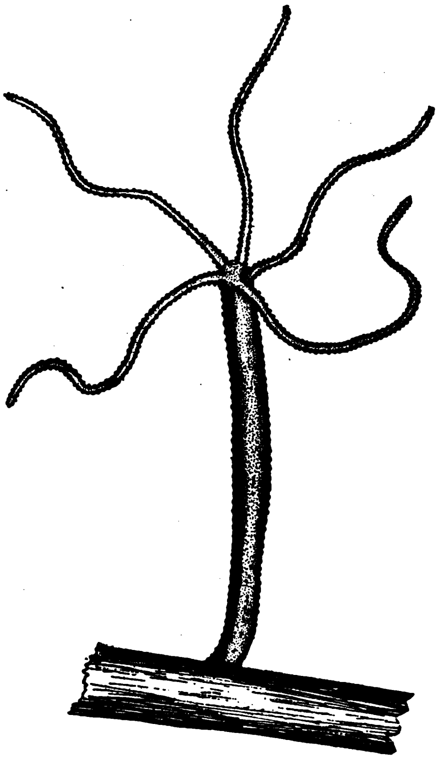

FIG. 16. — Fresh-water hydra fully expanded.

It must be remarked that the hydra has no muscle fibers like those of the higher animals with which movement is brought about. But many of the ectoderm cells have their

inner ends extended into narrow prolongations that run at right angles to the body of the cells. These narrow processes are called the muscle processes because they possess highly developed contractile power, and they serve to contract and expand the body.

The body of the hydra is attached by means of a sticky substance secreted by the posterior end, or foot. At times the hydra breaks this connection and moves in a peculiar manner to another location. It stretches out as far as possible, bends over, and grasps hold with its tentacles. Then it pulls the foot of the body close to the place where it has taken hold, thus forming itself into a loop. By repeating this action, it moves from place to place after the manner of a "looping," or "measuring" worm. At other times it takes hold with the tentacles and swinging the posterior end of the body slowly through the water turns a complete somersault. Then, occasionally, it crawls slowly along by means of its tentacles alone.

Structure of the body. — The body of the hydra is a long, cylindrical sack, closed at one end and open at the other. The walls of the body are composed of three layers of tissue: an outer layer of cells, the *ectoderm;* an inner layer of cells, the *endoderm;* and between these two layers, a third layer, of gelatinous, non-cellular tissue called the *mesoglœa.* The body cavity, or digestive cavity, since in this animal they are one and the same, extends throughout the whole length of the body and opens outward through the mouth between the bases of the tentacles. The tentacles are also hollow and open into the body cavity (Fig. 17).

Method of obtaining food. — There are in the ectoderm of the body, and especially of the tentacles, certain large cells, known as the *stinging thread cells.* Each stinging cell con-

tains an ovoid capsule filled with a peculiar, irritating fluid. Within the capsule and surrounded by the fluid is a long, slender, hollow thread coiled into a spiral. If, by chance, a foreign body — for instance, a tiny crustacean — comes in contact with a tentacle, the latter is stimulated to action and quickly winds about the foreign body. Then from each stinging cell the coiled thread, which is hollow, quickly rolls out as a glove finger is turned inside out. The poisonous fluid is then discharged directly into the wound through the hollow in the thread.

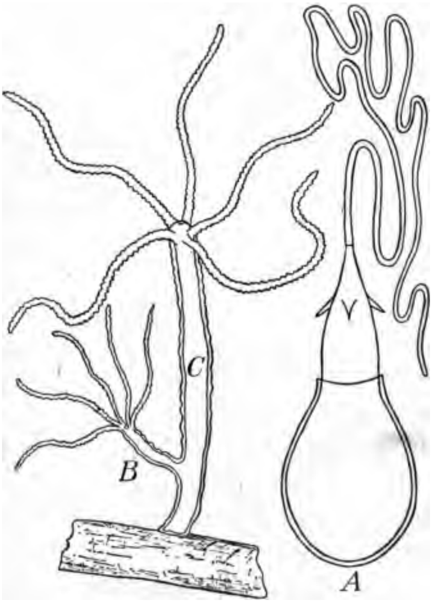

Fig. 17. — Diagrammatic drawing of a hydra: *A*, stinging thread cell; *B*, bud; *C*, body cavity.

Means of protection.—The hydra also protects itself from its enemies by means of the stinging thread cells. When an enemy approaches within reach, the stinging threads are shot out from many different cells, and the antagonist, if not too large, is overcome by the poisonous fluid. Even if not overcome, the enemy is often frightened into retreat.

How the hydra breathes. — This primitive animal has no special organs of respiration. It takes oxygen into its

body through all parts of the surface and gives off carbonic acid gas from all of its cells. In other words, each cell of the body performs the act of breathing for itself, independently of every other cell.

How the hydra digests its food. — The food, as we have seen, enters the mouth and passes directly into the large digestive cavity, which is uniform throughout its whole length and not differentiated into stomach, intestine, etc. But some of the endoderm cells lining this cavity secrete a digestive fluid which breaks up and dissolves the food to some extent. Probably particles of this food are then taken up by other of the endoderm cells and digested within them by their own protoplasmic mass. The ectoderm cells obtain their nourishment from the nutritive matter in the endoderm cells.

The hydra's manner of excretion. — There is only one opening to the body of the hydra and all undigested portions of food are passed outward through the mouth, the same route through which they entered the body. As we have seen, carbonic acid gas is given off through all parts of the surface. There are no special organs of excretion.

Reproduction of the hydra. — These little animals reproduce by budding and by eggs. An individual is often found with a smaller hydra growing out from the side of its body. The smaller one arises by a process of budding. The body wall of the parent bulges out at some point, forming a bud-like protuberance which enlarges and develops at its free end a mouth and tentacles, thus becoming a well-developed hydra (Fig. 17). The body cavity of the young hydra is continuous with that of the parent (Fig. 17). After a time these bud hydræ become detached and they then pass a separate existence.

True eggs are also produced by the hydra. The ovary containing the ova is situated in the body walls near the posterior end of the body. The sperm cells are produced in the walls just below the tentacles. When mature, the ovum is fertilized by the sperm, settles to the bottom, and after lying dormant awhile develops into an adult.

Regeneration of lost parts. — Many animals are similar to plants in their ability to reproduce lost organs and parts. If a hydra is cut in two near the middle, each part will reproduce the lost part, thus producing two hydræ where formerly there was one. If a hydra is cut into several pieces, each piece, under favorable conditions, will produce a new hydra. Where conditions are favorable to life, a hydra can hardly be killed by mutilation. Hydræ may be cut into pieces and the pieces may be grafted together in all sorts of ways and yet thrive and grow vigorously, as related by Professor Morgan in his interesting book on "Regeneration."

The Campanularian Hydroid

Class I. — Hydrozoa (water animals)

The branch Cœlenterata is divided into several classes, representatives of which will be briefly discussed and compared with the hydra.

The hydrozoans are Cœlenterata living in water, either fresh or salt. Some of them are simple in structure, like the hydra, and some of them are very complex, both in structure and development.

Campanularian hydroid. — This is an exceedingly delicate and beautiful organism found growing in the sea attached to seaweeds, rocks, sunken timbers, etc. It is known as a

colonial animal because it is made up of two kinds of "individuals," or, as they are called, *zoöids*, each kind of zoöid having a special function to perform. The zoöids are borne on a common, slender stem, or axis, and one kind is known as the nutritive zoöids while the other kind is known as the reproductive zoöids.

The axis may be said to consist of two portions, a horizontal portion which runs over the rocks and weeds in a horizontal direction (Fig. 18, *a*), and a vertical portion which consists of vertical stems arising from the horizontal part of the axis. Moreover, the vertical stems give off lateral branches in an alternate manner and the nutritive zoöids are borne on the outer ends of these lateral branches. All of the different portions of the axis are about the size of cotton threads, hence this animal is visible to the unaided

FIG. 18. — Campanularian hydroid : *a*, horizontal branch; *pr*, perisarc; *rp*, reproductive zoöids; *nt*, nutritive zoöid; *c*, cœnosarc.

eye. Because of the alternate lateral branching of the vertical stems, the animal shows a striking resemblance to a plant.

Usually, near the base of the vertical stem bearing the zoöids will be found one or more club-shaped cavities, formed at the ends of short lateral branches. These capsules are closed at the free ends and contain within them the reproductive zoöids (Fig. 18, *rp*). While within the transparent capsule the reproductive zoöids are mere buds and are called *medusa buds*. After a time the capsules break open and the medusa buds pass out, one by one, and are then known as *medusæ*, and sometimes jellyfish. They are umbrella-shaped and are found floating with the convex side uppermost.

After a time these medusæ produce eggs that finally develop into the plantlike, colonial organism with which we started.

Jellyfishes

Class II. — Scyphozoa (cuplike animals)

Nearly all of the large jellyfishes belong to this class and, in general, it may be said that the members of this class are larger than those of the Hydrozoa. Moreover, the majority of the Scyphozoa swim freely on the surface of the ocean. A few are found to inhabit the ocean at great depths.

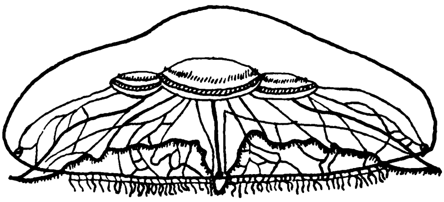

Fig. 19. — Jellyfish (*Aurelia*).

The common jellyfish, Aurelia. — This is a true jellyfish and has a convex, tough, jellylike body and is often found

floating on the surface of the sea (Fig. 19). In the center of the under surface of the body is the mouth. Above the mouth is the stomach, and higher up, from the end of the digestive cavity, canals radiate like the ribs of an umbrella. These canals extend downward along the inside of the dome and finally communicate with a circular canal around the edge of the disk. This system of tubes constitutes the water vascular system.

FIG. 20. — Embryo of jellyfish (*Aurelia*).

Aurelia has an interesting and complex life history. The adult produces eggs, each of which hatches into a ciliated

FIG. 21. — Hydralike stage of Aurelia. After Agassiz.

embryo (Fig. 20). The embryo soon attaches itself to a rock and transforms to a hydralike animal about one half

an inch high (Fig. 21). After eighteen months this form begins to increase greatly in length and becomes marked off into many transverse divisions by circular, transverse constrictions so that it resembles a pile of saucers with

FIG. 22. — Hydralike stage of Aurelia; saucer forms. After Agassiz.

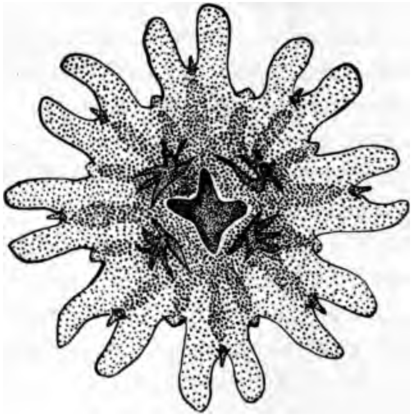

FIG. 23. — Saucer stage of Aurelia.

scalloped edges (Fig. 22). Finally, each division, or saucer, breaks away, swims off, and is known as an ephyra (Fig. 23). The ephyra, with a few changes, soon develops into the adult, umbrella-shaped jellyfish.

SEA ANEMONES, CORAL POLYPS, ETC.

Class III. — Actinozoa (raylike animals)

The Actinozoa occur in the sea, in both deep and shallow water, and are often of brilliant hues. They are of the same general structure as the hydra, but differ in that the mouth opens into a short, distinct gullet, which, in turn, opens below into the stomach, or body cavity. They also differ in

having vertical partitions that divide the lower part of the body into distinct compartments. In these two respects the Actinozoa show a decided advance over the Hydrozoa and the Scyphozoa.

Sea anemone. — There are many species of sea anemones, but a common one, known as Metridium (Fig. 24), will serve as an example, since they are all much alike. This one is found along the seacoast from Maine to New Jersey, attached to piles of bridges, rocks, or sunken timbers. Metridium has a soft, leathery, cylindrical body, varying from three to eight inches in diameter, when fully expanded. At the base, this cylinder is slightly expanded to form a large sucker, by means of which the animal attaches itself. The free end of the body is covered by a membrane and has a thick crown of tentacles, arranged around the edge, leaving an open space in the middle, in the center of which is an aperture, the mouth. This opens directly into the gullet, which is an oval sack suspended from the membrane covering the end of the body. The gullet opens below into the stomach, or body cavity. The gullet does not hang freely

FIG. 24. — Sea anemone.

suspended, but is supported by numerous radial partitions that extend from it to the body walls. Between these are other partitions that do not reach the gullet, one edge being free (Fig. 25). The reproductive organs are attached to the faces of these vertical partitions. The tentacles are hollow and open directly into the body cavity. They are expanded by a contraction of the body wall, which forces the water contained in the body cavity up into the hollows of the tentacles, thus causing them to extend and enlarge. The food is caught by the tentacles and passed into the mouth. The whole body, when the animal becomes alarmed, contracts and shrinks into a shapeless mass, by simply expelling the water in the body cavity. When all is quiet again, it slowly draws in water, and gradually expands to its former size.

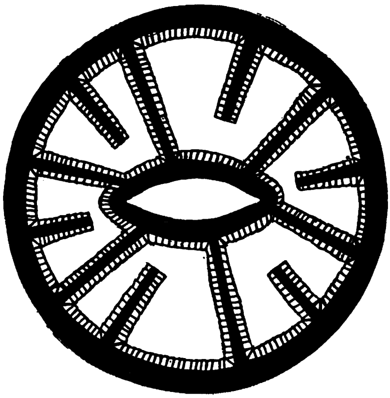

FIG. 25. — Diagram of a cross section of a sea anemone.

Other sea anemones. — There are many species of sea anemones and they are of various sizes and colors. They are abundant along the seacoast, and resemble flowers so much that they are popularly known as "sea flowers." Most sea anemones can detach themselves and move from place to place. The tentacles are constantly but slowly moving, and often, when stimulated by contact with foreign substances, they attempt to carry the particles to the mouth of the animal.

Coral polyps. — Most of the sea anemones are simple, *i.e.* each animal is separate, living by itself, although it may reproduce by budding. On the other hand the coral polyps, although they are very similar to the sea anemones in structure, are usually compound, and live in colonies. These are the animals that mainly build up the great coral reefs, found so abundantly in the Pacific Ocean. The structure of each little animal, or polyp, as it is called, is so similar to that of the sea anemone that it needs no further

FIG. 26. — Corals: *A*, tree coral; *B*, tree coral; *C*, head coral.

description here. A coral polyp differs from a sea anemone greatly in one particular, however; viz. in the power to secrete lime carbonate. This mineral substance is secreted by the ectoderm of the lower part of the polyp. In a large colony of polyps in which new individuals are constantly appearing, and in which each individual is adding its share of lime carbonate to the secretions of the others, there is finally built up in the process of time a great mass of lime carbonate. The shape of this mass will depend upon the species of polyp building it.

It must be borne in mind that coral reefs are not always built by coral polyps alone. Other animals and oftentimes certain plants aid greatly in building up reefs. Nevertheless, the principal reef builders belong to the group of animals known as coral polyps. Some of the species of corals grow and branch like a tree (Fig. 26), finally attaining a great size and producing an immense coral forest, as it were, which, in time, may reach the surface of the sea. In such an event the ends of the living branches of coral may extend out of the water at low tide. The waves then break off pieces of coral, which, together with other débris floating on the sea, fill up the spaces between the ends of the branches until the top of the reef becomes a solid, smooth surface. More material lodges on top, seeds fall there, and finally the reef becomes clothed with verdure.

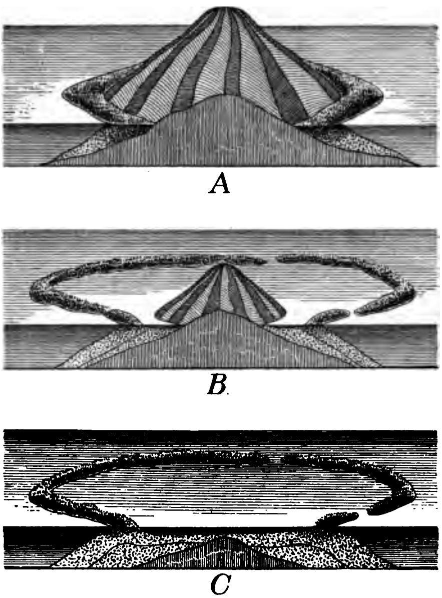

Fig. 27. — Diagram of coral reefs.

There are three kinds of coral reefs; viz. fringing, barrier, and circular reefs, or atolls. A fringing reef (Fig. 27, *A*) lies close to the shore of an island or continent. A barrier reef (Fig. 27, *B*) is separated from the

mainland by an intervening lagoon of water of varying depth and width. An atoll is, generally speaking, an oval reef inclosing a lagoon of water but no land (Fig. 27, *C*).

Coral polyps, with few exceptions, cannot live more than fifteen or twenty fathoms below the surface of the water, or in water that goes below 68° F. in temperature, or in fresh or in muddy water. Therefore, in order that the polyps may begin a reef, they must have rock for a foundation that is not over one hundred and twenty or thirty feet below the surface of the clear, briny sea.


Fig. 28. — Branch of red coral.

Not all corals, by any means, build reefs. Some polyps bud in such a manner as to form hemispherical masses of coral, varying from a few inches to several feet in diameter. Such an aggregation of polyps is called a head coral (Fig. 26). Other globular masses have their outer surfaces covered with serpentine furrows which cause them to resemble brains, hence they are called brain corals.

Finally, there is the red coral of commerce (Fig. 28), which was formerly so largely used for ornament. Of course the red part worn is but the hard lime secretions of the little polyps. When living, these red branches are wrapped in a layer of flesh much as the wood of a tree is wrapped in bark. The polyps, which are creamy white and have eight

tentacles, live in small holes in this layer of flesh, at right angles to the red stem within. When undisturbed, they project beyond the opening with tentacles spread out to catch food; but when irritated, they withdraw into the hole for protection.

Sea Walnuts

Class IV. — Ctenophora (comb bearers)

These are peculiar jellyfishes, mostly small, which spend a free-swimming life and, so far as is known, never form colonies. Neither is there at any stage of their existence a polyp form as in other Cœlenterata we have studied. These organisms are extremely delicate and are usually perfectly transparent. They swim by means of cilia and many of them are highly phosphorescent.

Alternation of generations among the Cœlenterata.—Like many of the lower plants — fungi, mosses, and ferns — many of the lower animals show what is known as an *alternation of generations.* This phenomenon is shown by the campanularian hydroid, the aurelia, and other cœlenterates of which we have not spoken. It will be recalled that a generation of each of two dissimilar individuals — the plantlike form and the medusa — was necessary to complete the full life history of the campanularian hydroid. Moreover, these generations followed each other alternately; the medusa giving rise to the plantlike structure, and the plantlike structure giving rise to the medusa, and so on indefinitely. Again, the campanularian hydroid may be said to exist under two different forms. This is called *dimorphism* (*di*, two; *morphē*, form). Some animals that exist under more than two forms are said to be polymorphic.

Relation of this branch to the sponges. — The members of this branch resemble the sponges in their fixed mode of living, in their manner of forming colonies by budding, in the possession of one body cavity, and in certain other ways too intricate to mention here. Hence, it seems that this branch stands nearer the sponges than any other branch of the Metazoa, but is higher in the scale than the sponges. For instance, we find the beginnings of a nervous system. In some of the jellyfish the nervous system consists of two rings of nerve matter around the edge of the umbrella. This is the first example of a concentrated, well-defined nervous system. The nervous system in the sea anemones consists of nerve cells and fibers irregularly disposed throughout the body. The methods of reproduction are more specialized than in the sponges, as are also the mode of living and the life history.

Adaptations to mode of living and environment. — An animal, to live, must have food. This food must either be brought to the animal, or the animal must go to it. Many of the animals in the foregoing branch are fixed and cannot go to their food. Such members have long, slender tentacles with which they can catch the food as it passes by and convey it to the mouth, — notably the fresh-water hydra. The hydractinia, a complex cœlenterate, is even better adapted than this. It attaches itself to the shell of the hermit crab, and is thus carried to new fields of food. At the same time it falls heir to minute morsels of the crab's food. It pays for all this, however, by affording protection to the crab, of which we shall speak later.

It will be remembered that nearly all of the Cœlenterata are soft-bodied animals. In the ocean they are always surrounded by hordes of enemies, who would quickly

devour them, were it not for the stinging cells with which they are all so plentifully provided. The Portuguese man-of-war is even dangerous for a man to handle. At the same time the thread cells furnish splendid weapons for paralyzing the prey used as food.

It is said that small fishes, as the butterfish, swim beneath the bell of one of our large jellyfishes for the purpose of being protected. This may be taken as good proof that the protection afforded by the thread cells is effective.

Economic importance of the cœlenterates. — Perhaps the cœlenterate that represents the most direct economic importance is the one that produces the red coral used for ornament. The main coral fisheries are on the coasts of Algiers, Tunis, and Morocco. Naples is the center of the coral trade. The prices vary according to color. Large pieces of the finest rose pink are valued at from four hundred to five hundred dollars an ounce, but small pieces of the paler colors, used for children's necklaces, are worth one dollar to one dollar and a half an ounce.

Indirectly, the different species of coral polyps are of economic importance because of the extensive areas of land built up by them. Many islands in the Pacific are examples of this land building through the agency of coral polyps. The most noted example, in our own country, of the part played by coral polyps in building up land is found in the present State of Florida. Much of the southern part of this State has been formed through the agency of these small animals. This has been accomplished through successive lines of coral reefs built parallel with the shore of the mainland, and through the filling up of the open channels between with silt, driftwood, and other decaying material.

CLASSIFICATION OF THE CŒLENTERATES

BRANCH III — Cœlenterata.
- *Class* — Hydrozoa.
  - Order — Hydromedusæ (Leptolinæ).
    - Types of the Order.
      - *Hydra viridis* — Hydra.
      - *Hydractinia echinata* — Hydractinia.
      - *Eucope species* — Campanularian hydroid.
  - Order — Siphonophora.
      - *Physalia arethusa* — Portuguese man-of-war.
- *Class* — Scyphozoa.
  - Order — Discomedusæ.
    - Type of Order.
      - *Aurelia flavidula* — Jellyfish.
- *Class* — Actinozoa.
  - Order — Actinaria.
    - Type of Order.
      - *Metridium marginatum* — Sea anemone.
  - Order — Madreporaria.
    - Type of Order.
      - *Madrepora species* — Coral polyps.

VIII. FLATWORMS, ROUNDWORMS, AND ROTIFERS

BRANCHES IV, V, VI, AND VII. — Platyhelminthes (Flatworms), Nemathelminthes (Roundworms), Trochelminthes (Rotifers), and Molluscoidea (Lamp Shells)

IN this chapter we shall discuss examples of four branches the members of which, heretofore, have all been included in one branch, Vermes (worms). The individuals, commonly placed in the branch Vermes, differ so much among themselves that the later authorities put them in different branches. The members of the above branches are more or less wormlike in character and appearance. The body of the earthworm, as we know, is divided into rings, or segments; but no true segments are found in the simpler worms. The animals treated in this chapter are perhaps the most widely distributed of all the many-celled animals. Some are found from the shallowest to the deepest water in rivers, lakes, and seas; some live on the land; while some live as parasites in many different species of the multicellular animals.

FLATWORMS

The flatworms include a great variety of forms that differ widely from each other in habits and appearance. The majority have flattened, more or less leaflike bodies; a few have approximately cylindrical bodies. The fresh-water flatworms, found on the bottoms of ponds among the sediment and leaves, are from one eighth of an inch to nearly half an inch in length. Their bodies are flat, thin,

and usually taper to the posterior end. They have two eyes on the upper surface of the body at the anterior end. It is of the parasitic flatworms that we wish especially to speak, namely, the flukeworm and tapeworm.

FIG. 29.—Flukeworm.

Flukeworm.—This worm has a flattened, leaflike body (Fig. 29), from three fourths of an inch to two inches in length. It is parasitic in the livers of sheep and cattle, especially the former, and causes the disease known as *liver rot.* It is now known to exist in this country, but is especially prevalent in England, and causes the loss of many sheep there annually. The adult worm has two suckers at the anterior end of the body for attachment to its host. While in the liver of the sheep the worm lays great numbers of eggs which find their way to the intestines of the host and thence to the outside world. If an egg falls on dry ground, it usually perishes; but if it falls on damp herbage or in water there hatches from it a minute, ciliated embryo (Fig. 30). This embryo swims about in the water until it finds a certain species of snail. It then actually bores its way into the body of the snail, and after undergoing complicated changes transforms to an elongated body called a *redia* (Fig. 31). After a time, there are formed within the redia certain bodies called *cercariæ.* Each cercaria, which is provided with a long tail, eventually escapes from the redia and forces its way

FIG. 30.—Embryo of flukeworm. After Thomas.

out of the body of the snail, crawls up the stem of a plant or blade of grass and secretes about itself a *cyst* or hard film of gelatinelike substance. In these situations it is eaten by the grazing sheep. In the stomach of the sheep the cyst is dissolved, and the immature worm soon works its way to the liver, where it grows and becomes mature, thus completing the life history.

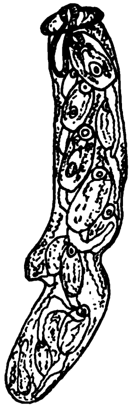

FIG. 31.—Redia form of flukeworm as it appears in the body of the snail, showing cercariæ. After Leuckart.

FIG. 32. — Cercaria form of flukeworm. In this form it escapes from the snail's body, climbs a blade of grass, and becomes encysted. After Leuckart.

Tapeworm. — There are several species of tapeworms, all of which are parasitic in their adult stages, in the bodies of vertebrates, as, man, cattle, dog, sheep, birds, fishes, etc. At least three different species are fairly common as parasites in the intestines of man, but we shall speak of only one here, namely, the pork tapeworm.[1]

FIG. 33. — Head of tapeworm showing suckers and hooks. Greatly enlarged.

Like the flukeworm, the tapeworm passes the larval stage of its life history in one animal and the adult stage in

[1] Dr. Charles Wardell Stiles says that the pork tapeworm is comparatively rare in this country, and that the beef tapeworm is the most common one here. Bull. 19, U. S. Dept. Agri. B. A. I., 1898.

another animal. As seen in the mature stage in the digestive tract of man, the tapeworm has a head about the size of the head of a pin. The crown of this tiny head is beset with many minute hooks and the sides of the head are furnished with suckers (Fig. 33). All of these are for attachment to the host. The head is followed by a very short, slender neck. The body, from the neck on, has a jointed appearance owing to its being divided into jointlike divisions called *proglottids*. The body varies from twelve to twenty-four feet in length and from one quarter to two fifths of an inch in width, but is thin and tapelike, hence its name (Fig. 34). About half, and sometimes more, of the proglottids are capable of producing eggs. When the terminal proglottid becomes gorged with eggs, it breaks away from the others and passes out of the host's body. The succeeding terminal proglottid, in time, does the same thing and is followed by others until many segments full

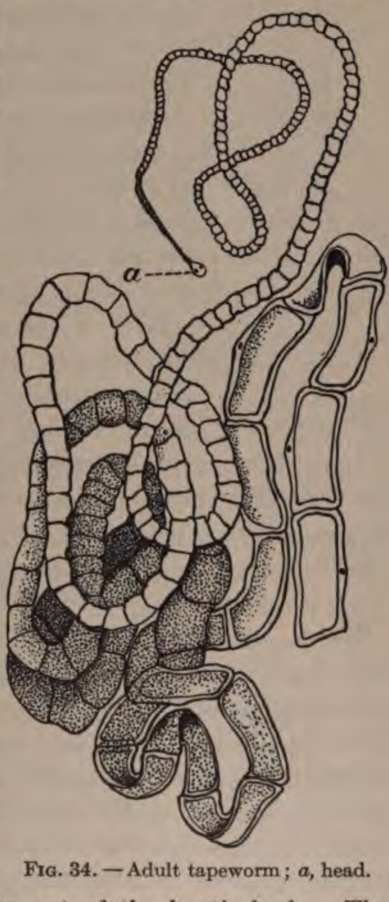

FIG. 34. — Adult tapeworm; *a*, head.

of mature eggs have been given off from the body. The eggs are carried away into ditches and waste places, where they may be eaten by pigs. The embryos soon hatch from the eggs in the intestines of the pigs, and immediately bore their way through the tissues to the muscles of the animal. In this situation the embryo changes into a flask-shaped form, known as the larva (Fig. 35). The presence of these larval tapeworms in the muscles of the pig give to the pork an appearance that causes it to be known as "measly pork." When such pork is eaten raw or insufficiently cooked, the larvæ soon develop into mature tapeworms in the digestive tract of man.

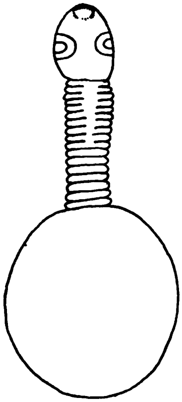

FIG. 35. — Larva of tapeworm.

It is best to cook pork thoroughly before eating it, although tapeworms are not usually fatal to life. This rule of prevention also applies to the beef tapeworm.

ROUNDWORMS

On the whole the members of this group are more wormlike than the flatworms. Their bodies are, in general, cylindrical but unsegmented. Many of the roundworms are parasitic. Perhaps the small worms so often seen in strong vinegar and known as "vinegar eels" are the most familiar examples of the roundworms. The nematode worms that live in soil and attack the roots of certain plants, causing galls to form on the roots, are also more or less familiar. To this group also belong the so-called "hair worms," or "thread worms" (Fig. 36). These long slender worms are often found in drinking troughs and so much

resemble hairs that some people think they are transformed horse hairs. The guinea worm, which is a parasite of man in tropical countries and which sometimes attains a length of several feet, is a member of the group of roundworms.

FIG. 36. — Hair worm.

Trichinella spiralis. — This is one of the most important roundworms, economically speaking, in the United States. The adult worm is very small, scarcely visible to the naked eye, and is found only in the intestines of mammals, as, man, pig, rat, etc. It is probable that the pig becomes infested with this worm by eating the flesh of some animal, as the rat. Of course man becomes infested by eating raw or half-cooked pork. In this way the worms, in a larval condition, are taken into the alimentary canal. There they soon become mature, and the young are produced in immense numbers. These soon work their way through the walls of the intestines and finally reach the muscles (Fig. 37), where they become surrounded with a cyst, and there they remain. Before forming the cyst, the embryos feed upon the muscular tissue, causing serious complications that often result in the death

FIG. 37. — Trichinella spiralis imbedded in human muscle. After Leuckart.

of the host. The number of larvæ that may be encysted, at one time, in the muscles of a human being is enormous. It has been estimated that, by eating an ounce of "trichinosed" pork not well cooked, eighty thousand worms might be set free in the intestines.

Prevention. — Thoroughly cook every bit of pork eaten. If practicable, feed only vegetable products. If swill containing scraps of pork is fed to hogs, always cook it thoroughly before feeding.

Rotifers, or Wheel Animalcules

The third branch which we discuss in this chapter is represented by the miscroscopic animals known, as rotifers, or wheel animalcules. These interesting animals are abundant in fresh-water ponds, pools, puddles, and streams, and a few occur in the sea. They are almost sure to be met in aquaria. The majority are free-swimming, but a few are fixed in the adult state. Although these animals are microscopic they have distinct digestive and nervous systems and a complex body structure.

Figure 38 shows the form and appearance of a rotifer common in fresh water ponds. The body has two regions — a broad portion, the *trunk*, which forms the greater part of the body, and a rather long, slender portion, the *tail*. The trunk is inclosed by a glassy, transparent cuticle. At the anterior end of the body is an organ known as the *trochal disk*. The edge of the disk is fringed with cilia, which by their peculiar motion give the appearance of a wheel rotating. This disk, with the cilia and apparent rotary motion, is a distinguishing feature of these animals and gives them their name, Rotifera. The anterior portion of the body may be withdrawn into the

glassy cuticle of the trunk, and the tail is freely movable and is often lashed from side to side with sudden jerks.

Rotifers are remarkable in two respects. First, the female lays two kinds of eggs, — summer eggs and winter eggs. The former have thin shells, and the latter thick shells which protect them from the cold. The second remarkable characteristic is, that the bodies of rotifers will shrivel and dry up during a drouth, but when again brought into the presence of moisture, even after three or four years, will revive. This accounts for the sudden appearance, after a rain, of rotifers in ditches that have been dry for months.

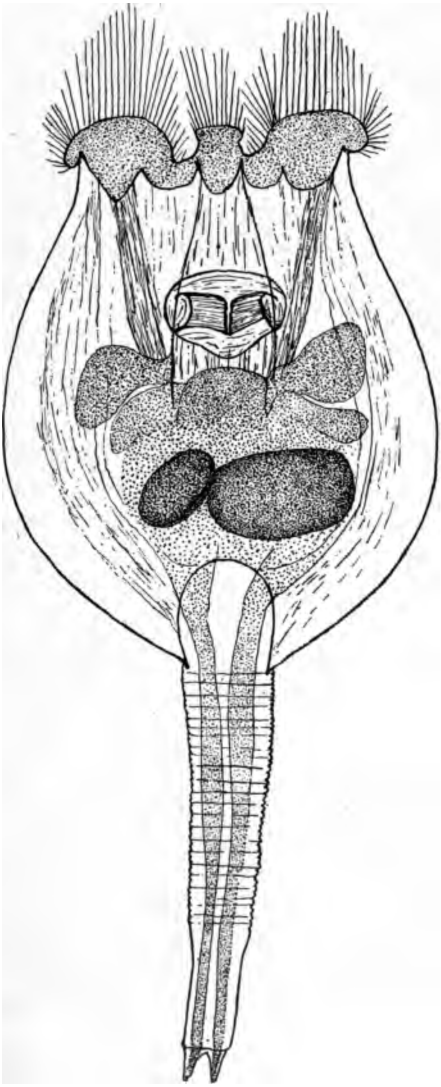

FIG. 38. — A rotifer.

Lamp Shells

These animals are representatives of a class containing several widely different forms. The lamp shells resemble mollusks because their bodies are inclosed in bivalve shells. But the valves are dorsal and ventral, whereas the valves of the shells of a clam are right and left and similar. In many of these animals, the shells are shaped like an old Roman lamp, hence the name.

They are all marine and many of them are attached to some object in the sea by a fleshy stalk, or peduncle. They are remarkable for the fact that their shells are found in nearly the oldest rocks in the earth and are very little different from the forms existing to-day.

Relationships and noteworthy features of the worms. — The relationships of these animals are very uncertain. It is thought, with reason, that the foregoing groups of worms are most closely related to the cœlenterates, and so they closely follow in the scale of progression.

One thing is preëminently characteristic of some of the worms, namely, the strange and remarkable changes they pass through in completing their life history, notably the liver fluke. Moreover, it will be recalled that part of the life history of certain worms is passed inside the body of one host and another part of the life history within the body of a second and very different host. Again, certain worms are able to live and thrive within the bodies of several different animals. Another noteworthy feature of many worms is that they are parasitic and cause certain malignant diseases when present in man.

The worms are also well adapted to maintain themselves on the earth. Their ability to live in different hosts, in

varied situations, and on water and land show this. Recall that the rotifers lay two kinds of eggs to meet different conditions and maintain an existence.

Progression. — It is evident that the animals discussed in these four branches are more highly developed than those of the foregoing branch. Starting with the flatworms, we find that many of them have a rather complete digestive system and concentrated nervous system. The digestive system of the flukeworm consists of a mouth, pharynx, gullet, and intestine, while the nervous system consists of a ring of nerve matter around the gullet which gives off a number of nerves, one pair running the length of the body. Trichinella has a mouth, pha ynx, and intestine, with a ring of nerve matter about the pharynx that gives off nerves. The rotifers possess a mouth, pharynx, gullet, stomach, and intestine, — the most complete digestive system that we have seen so far. They also have a small brain.

CLASSIFICATION OF THE WORMLIKE ANIMALS

BRANCH IV — Platyhelminthes.
- *Class* — Trematoda.
  - Order — Digenetica.
    - Type of Order.
      - *Distomum hepaticum* — Liver flukeworm.
- *Class* — Cestoda.
  - Order — Polyzoa.
    - Types of Order.
      - *Tænia solium* — Pork tapeworm.
      - *Tænia saginata* — Beef tapeworm.

BRANCH V — Nemathelminthes.
- *Class* — Nematoda.
  - Order — Nematoidea.
    - Type of Order.
      - *Trichinella spiralis* — Trichina.

BRANCH VI — Trochelminthes.

Class — Rotifera.

Order — Bdelloïda.

Type of Order.

Rotifer species — Wheel animalcule.

BRANCH VII — Molluscoidea.

Class — Brachiopoda.

Order — Articulata.

Types of Order.

Various species.

IX. EARTHWORMS, LEECHES, AND SEAWORMS

BRANCH VIII. — Annulata (*annulus*, ring)

Annulata. — With very few exceptions the members of this branch have their bodies divided externally into a number of rings which represent a division of the internal parts into a series of segments. The segmented worms are widely distributed. They are found on land, in fresh water, and in the sea.

EXAMPLE OF THE BRANCH — THE EARTHWORM

External features. — The body is long and cylindrical, bluntly pointed at one end and rounded and flattened at the other. The bluntly pointed end of its body which bears the mouth is known as the *anterior end*. The opposite end of the body is known as the *posterior end*. At the anterior end of the body is a small lobe which overhangs the mouth and is called the *prostomium*, or "lip." A short distance back of the anterior end is a swollen ring, or band, called the *clitellum*. It is furnished with glands for secreting mucus to form the egg capsules. If a worm be carefully watched, it will be found that a certain side of the body is always held uppermost and away from the ground. This is called the *dorsal side*. The side of the body in contact with the ground is called the *ventral side*. Moreover, the body is plainly divided into *rings*, or *segments*. The segments seem to be marked off by super-

ficial wrinkles of the skin, but, in reality, a partition of thin tissue extends vertically through the body at every constriction and divides the body internally into as many compartments as there are segments.

Bilateral symmetry. — If, when the earthworm is in a natural position with the dorsal side uppermost, the body is cut lengthwise, exactly on the middle line, into two equal halves, the right half will be exactly similar to the left half. "This similarity is called two-sided likeness, or *bilateral symmetry*." It is a structure common to the higher animals and reaches its greatest perfection in the human body.

The general plan of the body. — The body of the earthworm is made up of two tubes, a small one within a con-

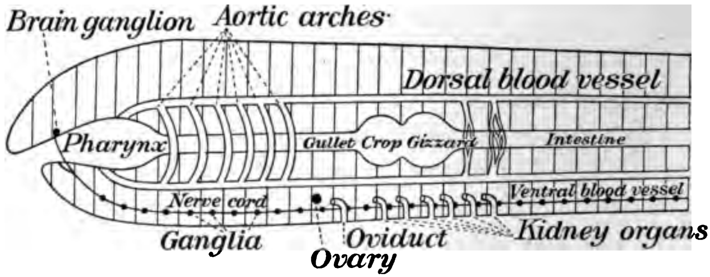

FIG. 39. — Diagram of the internal structure of an earthworm.

siderably larger one. The small, inner tube is the alimentary canal opening in front by the mouth and behind by the anus. The outer tube is formed by the body walls of the worm and since it is so much larger than the inner tube there is a space surrounding the alimentary canal but inclosed by the body walls. This space is known as the body cavity, or *cœlome.* Here again we find a structure common to the higher animals. Within the body of a sparrow or rabbit is a space surrounding the alimentary canal but

inclosed by the body walls that is termed the body cavity, or cœlome. In the earthworm, as we have already noted, the body cavity is divided into compartments by thin cross partitions (Fig. 39).

Structure of the body walls. — The body walls of an earthworm are made up of five distinct layers of tissue. The outer-

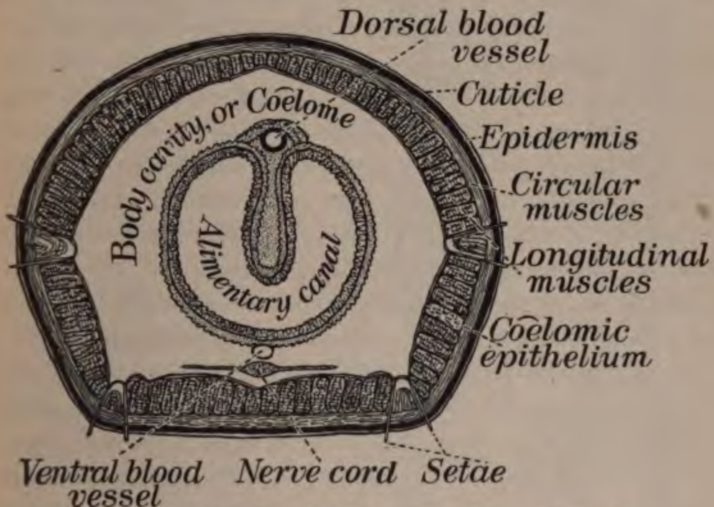

FIG. 40. — Diagram of a cross section of an earthworm.

most layer is a thin, transparent membrane called the *cuticle.* Just beneath this is the skin, composed of long cells placed vertically to the surface of the body like the palisade cells of a plant leaf. Next to the skin is a layer of muscles that encircle the body, hence called *circular muscles.* Within this layer is one composed of muscles that run lengthwise of the body, therefore known as the *longitudinal muscles.* Lastly is a very thin layer of flat cells called the *cœlomic epithelium.* This layer of cells lines the cœlomic cavity.

The notable thing about the body walls is the two layers of muscular tissue each composed of muscles running in opposite directions. The wriggling, crawling movements of this animal are produced by these two layers of muscles.

The bristles, or setæ of the earthworm. — The body of the earthworm is furnished with four double rows of stiff, chitinous bristles, or setæ. They may be felt by drawing the worm backward across the hand. There is one double row along each edge of the ventral surface and one double row along the lower part of each side of the body (Fig. 40). Each segment, except the first and last, has four pairs of setæ and each pair is provided with muscles so that the bristles may be turned and held in various directions, and extended or withdrawn. When a bristle wears out, it is cast off and a new one grows in its place.

Movement of the earthworm. — If an earthworm is placed on a piece of glass or other smooth surface, it will squirm and wiggle but will make no progress. It is capable of motion on a smooth surface but cannot change its location. This is because the setæ, which perform an important function in the locomotion of the animal, are unable to do their work on smooth surfaces. Under ordinary conditions the bristles stick into the soil and prevent the worm from slipping backward, when the muscles contract to force the body forward. On hard smooth surfaces the bristles are unable to get a hold and the worm, despite its struggles, remains in one place. When the worm desires to move forward, it points the setæ backward and they stick into the soil. The longitudinal muscles, which are then contracted, pull the posterior end of the body forward and shorten and thicken the whole body. The circular muscles now contract, thus forcing the body to become thinner and longer.

But since the setæ will not allow the body to slip backward, it is forced in a forward direction. By repeating these operations the worm progresses slowly from place to place. Very often the earthworm desires to travel backward, especially when it wishes to back quickly into its burrow. In this case the setæ are pointed forward and the same muscular contractions suffice for the backward movement.

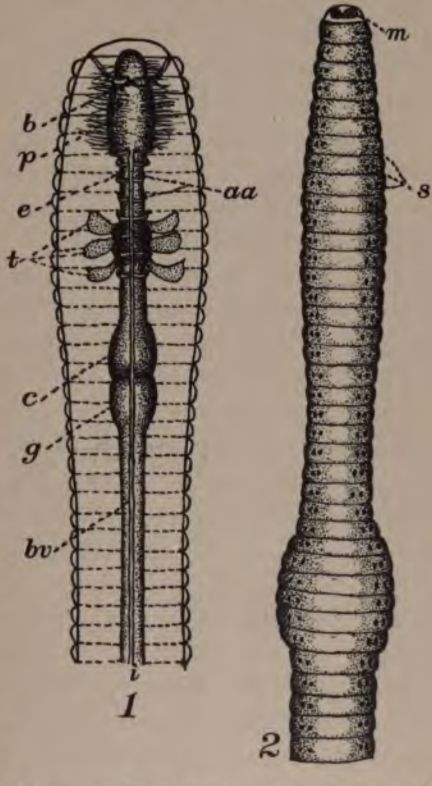

FIG. 41. — Earthworm: 1, anterior end opened along dorsal side; *b*, brain; *e*, gullet; *t*, seminal vesicles; *c*, crop; *g*, gizzard; *bv*, blood vessel; *i*, intestine; 2, anterior end; *m*, mouth; *s*, setæ.

The digestive system. — The alimentary canal runs straight through the body from end to end. It consists of several fairly distinct parts, each with its own peculiar function. The mouth is a simple, crescent-shaped opening at the anterior end of the body, and is overhung by the lip, or prostomium. This worm has no teeth nor tongue. Beginning at the mouth is the barrel-shaped pharynx, extending through several segments.

Its walls are thick, muscular, and capable of contraction and expansion. Following the pharynx is the slender, thin-walled gullet which extends through eight segments to the crop, a short reservoir formed by a dilatation of the alimentary canal. Adjoining the crop is the gizzard, a firm, muscular organ lined with a chitinous membrane. The remaining part of the canal answers both as a stomach and intestine. It is a straight, thin-walled tube without glandular appendages such as the liver and pancreas found in the higher animals (Fig. 41).

The process of digestion. — Digestion begins before the food even enters the mouth of the worm. A certain digestive fluid is poured forth from the mouth to moisten the food about to be eaten. It is thought that lime secretions from certain glands connected with the gullet mix with the food while passing through this organ and neutralize the acids produced by the leaves. The gizzard grinds the food and is usually aided in this work by fine sand. The main action of digestion goes on in the anterior part of the stomach-intestine.

The circulation of the earthworm. — This animal possesses two circulations, the cœlomic circulation and the vascular circulation, each being quite distinct from the other. The cœlome is filled with a colorless fluid which is driven to all parts of the body by contractions of the body walls. This fluid passes from one segment to another through holes in the thin cross-partitions. It is supposed that the nutritive portions of the food pass through the walls of the intestine into the cœlomic fluid and are thus carried directly to all the organs which this fluid bathes.

The blood, or vascular circulation is fairly well developed, for the blood is red and circulates through a system of

closed tubes. The red coloring matter, *hæmoglobin,* is dissolved in the liquid itself and is not contained in corpuscles as in the blood of mammals. The blood of the earthworm contains corpuscles, but they are colorless. Running along the dorsal side of the alimentary canal is a long, muscular tube that can be seen through the partly transparent skin of a living worm as a dark red band. This is the *dorsal blood vessel.* By close observation successive wavelike contractions may be seen to pass rapidly from the posterior end of this tube forwards. Lying beneath the alimentary canal is a similar tube, the *ventral blood vessel,* which carries the blood it receives from the anterior end of the dorsal vessel, posteriorly. There are also five pairs of short tubes that arch to the right and left around the gullet in the 7th, 8th, 9th, 10th, and 11th segments. These tubes, the *aortic arches,* connect the dorsal vessel with the ventral vessel and since they are contractile are often called the "hearts" of the worm. Smaller tubes branch off from these main ones and extend to different parts of the body.

How the earthworm breathes. — The earthworm has no lungs, gills, or other special organs of respiration. The thin walls of the moist skin are everywhere traversed by a network of minute blood vessels that lie just beneath the surface, so that they are separated from the air by only a very thin membrane. Oxygen is therefore easily absorbed from the air through all parts of the skin and conversely carbonic acid gas is given off by the blood and passes outward through the skin. This is a very simple form of respiration, but answers admirably for such an elongated, thin-skinned animal.

The excretory system. — As we have just explained, some

of the waste materials of the body are excreted through the skin in the form of carbon dioxide. But the principal organs of excretion are convoluted tubes, known as *nephridia*, a pair of which is found in each segment of the body except the first three or four and the last one. Each nephridium opens at one end to the exterior by a minute pore in the body walls between the upper and lower rows of setæ. The inner end of each nephridium has a funnel-shaped orifice lined with cilia that opens freely into the body cavity. These organs act as simple kidneys and carry off the waste matters of the body.

The nervous system. — This animal has a brain composed of two ganglia on the dorsal side of the anterior part of the pharynx. From each ganglion of the brain a nerve cord passes downward on the corresponding side of the pharynx. These cords meet below. Thus the pharynx is completely encircled by what is called the "nerve ring," or "esophageal collar" (Fig. 42). After the nerve cords meet they pass throughout the length of the worm on the floor of the body cavity and become so closely fused that they appear as a single cord. In each segment of the body both cords become enlarged and form a double ganglion which appears as one. Smaller nerves pass from these ganglia to different parts of the body (Fig. 42).

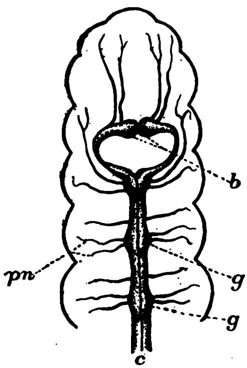

FIG. 42. — Anterior end of earthworm: *b*, brain; *g*, ganglia. After Leuckart.

Senses of the earthworm. — It has been shown that all parts of the skin of the earthworm contain cells each of which gives off a nerve fiber that runs directly to the large

nerve cord already described. This explains the fact that the sense of touch is well developed and extends over the whole surface of the body. It is thought that the sense of taste is located in the mouth and pharynx. Darwin has shown that the sense of sight, feeble though it is, is confined chiefly to the anterior end of the body, although the posterior end is sensitive to light. It is certain that the earthworm perceives the difference between darkness and light for it withdraws to its burrow during the daytime, and when a bright light is flashed upon the anterior end, it contracts. It has no eyes, and we have no reason to suppose that it is capable of forming pictures of objects. Neither is there evidence to show any sense of hearing.

Its food and how eaten. — The food of the earthworm comprises both animal and vegetable matter, the latter consisting largely of bits of leaves. Besides these articles of food it swallows large quantities of earth that pass slowly through the alimentary canal, during which passage the nutritive portions contained in it are absorbed and digested. This earth is usually obtained at a considerable depth, but the waste parts of it thrown off by the alimentary canal are deposited at the surface of the ground and form the so-called "castings" about the mouths of their burrows.

The pharynx is muscular and contractile. Moreover, muscles run from the outside of the walls of the pharynx to the inside of the body walls. These expand the pharynx, and if the mouth has been previously applied to any solid object, such as a leaf or pebble, the pharynx acts upon it like a suction pump and draws it into the alimentary canal if desired.

Regeneration of lost parts. — Earthworms are remarkable for their ability to withstand injury and to regenerate lost

parts. If one be cut in halves, the two portions, under favorable conditions, are capable of reproducing the lost halves with their organs, thus producing two complete worms. Moreover, the anterior half of one worm may be successfully grafted on to the posterior half of another.

Its life history. — Each earthworm produces both sperms and ova, but the ova are fertilized by the sperms from a different individual. About the time the eggs are ready to be laid, a band, or collar, is formed around the clitellum from mucus secreted by the glands of this organ. The collar, which is gradually slipped forward, receives the ova and sperms as it passes along and is finally worked off over the anterior end of the worm. The collar now becomes closed at both ends and forms a horny capsule containing the eggs. These capsules are deposited in loose earth, or under logs and stones, where they remain until the young worms emerge. Some of the eggs in each capsule do not hatch but remain to furnish food for the young worms produced from the other eggs.

The distribution and habits of earthworms. — There are many kinds of earthworms and they are found in all parts of the world. They live in the earth in burrows varying in depth from a few inches to several feet. They are nocturnal animals and spend the day hidden in their burrows with the head lying near the surface if the ground is moist. At night they come out in search of food, but usually remain with the posterior end attached at the mouth of the burrow, ready to disappear if danger threatens. They gather up bits of leaves for food and collect pebbles to line the upper parts of their burrows and to stop up the entrances after withdrawing the body. As the ground becomes dry in summer they burrow deeper and deeper into the soil and

seldom appear on the surface unless it rains. In winter they hibernate below frost line.

The economic importance of earthworms. — Mr. Darwin has shown that earthworms exercise a profound influence upon the surface soil. They are constantly depositing their "castings" upon the surface of the ground near the mouths of their burrows. This earth has been brought from considerable depths and carries whatever fertilizing constituents there may be at these depths below the reach of the roots of ordinary plants. Moreover, the earth, in passing through the alimentary canal of the worm has been worked over and its fertility increased. Therefore, earthworms may be looked upon, in general, as improvers of the soil. Darwin estimated that, if the castings of earthworms were spread uniformly over the surface of England, they would add two tenths of an inch every year to the thickness of the rich surface soil.

Leeches. — In many of our streams, lakes, swamps, and marshy places there exist segmented, half-parasitic worms, known as leeches, or "blood-suckers." Their bodies are somewhat flattened and in some species, at least, are capable of great distention. The bodies of most leeches have a sucking disk at both the anterior and posterior ends. By means of these suckers they cling firmly to the bodies of other animals. Sometimes the mouth is furnished with teeth and sometimes not. In some leeches the capacity of the crop is greatly increased by a series of pouches placed along the sides of the crop and communicating with it. In this way the crop is able to hold a supply of food sufficient to last the leech several months.

In the olden times it was the custom, among physicians, to "bleed" patients. For this purpose leeches were

employed, because they produced scarcely any pain, while sucking the blood. These worms are occasionally used for this purpose yet and are found for sale in some drug stores. Leeches are raised in France on a commercial scale. Swamps are stocked with them, and they are then fed on worn-out horses, cattle, etc.

Certain leeches, in India, that live on the land are great pests to the natives and domestic animals. Others are parasites, clinging to the bodies of fish, and one, the horse-leech, is sometimes parasitic in the throats of horses and cattle. Some are carnivorous, living on the bodies of snails and other mollusks. The eggs of leeches are usually inclosed in cocoons.

Seaworms. — There are many worms living in the sea. Some are free-swimming; some crawl along the bottom; some live in burrows, and some in tubes. Perhaps the majority of marine worms are found in shallow water along the shores of the sea, although some have been dredged from depths of over three thousand fathoms.

The tube-building seaworms are interesting creatures. Most of them lead a sedentary or fixed life. The tubes of some are formed from hardened mucus secreted by special glands of the body. Others make their tubes from grains of sand or mud or even from fragments of shells stuck together with mucus. A few are free and actually carry their tubes about with them.

Progression. — The earthworm and leech are probably the highest animals we have met so far. In the first place the bodies of both are truly segmented. That is, the cavity between the alimentary canal and the body walls, known as the cœlome, is divided into compartments by cross-partitions. Bear in mind that they are the first animals we have

met with segmented bodies. Moreover, these animals have a double nerve running throughout the whole length of the body and a distinct brain. Correlated with the brain, as we should expect, are eyes, at least, in some of the leeches and seaworms.

Adaptations to mode of living. — The home of the earthworm is in the soil. It burrows all through the soil in search of its food. The food is derived largely from quantities of soil, which are passed straight through the alimentary canal. To facilitate the passage of such a quantity of useless material the alimentary canal is straight. At the same time there must be a large amount of absorbing surface in the canal to take up the food contained in the soil, while it is passing through. To provide such a surface and yet not have the canal coiled, the body must be long, and so it is. More than this, the shape of the body is most economical for a burrowing animal without strong jaws or claws. That is, if the body of the worm were short and thick, a larger hole would have to be made and, consequently, more digging done. Again there are many setæ on the ventral side of the body which aid greatly in crawling up the sides of the burrow.

The leech is furnished with suckers, which certainly adapt it to its mode of life. Moreover, the crop is sometimes enlarged by lateral pouches, that it may hold sufficient food to last the animal for a long time. Finally, the body can be greatly distended to provide room for the storage of food. Undoubtedly leeches often go several weeks without finding an animal whose blood may be drawn. If it were not for the enlarged crop and extensible body, in which the blood can be stored to tide over the intervals when no food is obtainable, the animal might die.

CLASSIFICATION OF THE HIGHER WORMS

BRANCH VIII — Annulata.
- *Class* — Chætopoda.
  - Type of the Class.
    - *Lumbricus agricola* — Earthworm.
- *Class* — Hirudinea.
  - Types of the Class.
    - *Hirudo medicinalis* — Medicinal leech.
    - *Hæmopis vorax* — Horse-leech.
    - *Macrobdella decora* — American leech.

X. STARFISH, SEA URCHIN, BRITTLE STARS

BRANCH IX. — Echinodermata (*echinos* (spine), hedgehog; *derma*, skin)

MOST of the members of this branch have the surface of the body beset with spines; hence the name, Echinodermata, meaning spiny skins. In all the echinoderms the parts of the body are arranged in a radial manner. In nearly all there is an exoskeleton composed of calcareous plates. Without exception they are found in the sea.

AN EXAMPLE OF THE BRANCH — THE STARFISH

The form and radial symmetry of the starfish. — The common starfish has a star-shaped body consisting of a central portion known as the *central disk*, and five tapering arms. The arms radiate from the central disk much as the spokes of a wheel radiate from the hub. This radial arrangement is characteristic of all members of this branch and is known as *radial symmetry* (Fig. 43).

FIG. 43. — Ventral surface of a starfish.

External features. — In its natural position, one side of the body is always uppermost. This side is called the

aboral surface. The opposite side is called the *oral surface* (Fig. 43). In the center of the oral surface is an opening, *the mouth.* Radiating from the mouth are five grooves, one along the median line of the oral side of each arm. These are the *ambulacral grooves.* The whole body is beset with many stiff spines. Bordering each of the ambulacral grooves there are two or three rows of spines that are movable. These are the *ambulacral spines.* On the aboral surface, between the bases of two arms, is a small circular plate, the *madreporite,* which is marked by a number of fine, straight, or wavy ridges and perforated with many minute openings.

The tube feet.—In each of the ambulacral grooves there are two double rows of soft, flexible, and cylindrical bodies, the *tube feet.* Each tube foot is a hollow cylinder, ends with a sucker, and can be greatly extended or contracted. These are the organs of locomotion.

Structure of the body walls. —The body walls consist of three layers: an outside layer of thin *epidermis* that covers the whole body; a middle and much thicker layer, *the mesoderm,* and a delicate inner layer, the *cœlomic epithelium.* The latter not only lines the whole body cavity, but forms an outside covering for the internal organs.

Skeleton. —The body of the starfish is inclosed in a hard, rough integument, the skeleton, consisting of many small, irregular, calcareous plates, termed *ossicles.* The ossicles are loosely joined together by a connective tissue so that the skeleton is more or less flexible and a certain amount of movement is permitted. The skeleton is beneath the epidermis and is developed from the mesoderm.

In the spaces between the ossicles, on the dorsal surface, there are several minute pores in the connective tissues.

Through these openings, very small, soft, fringelike projections of the inner body-lining protrude. These are the *branchiæ*.

The digestive system of the starfish. — The mouth opens into a short gullet that leads to a five-lobed sac, the stomach. The stomach is large, thin-walled, and very extensible. It is divided into two portions by a constriction in the middle. The lower part is called the *cardiac portion*, and the upper part is called the *pyloric portion*. The pyloric division opens into a short intestine that leads to a very small anal aperture on the dorsal side of the body.

FIG. 44. — Upper walls of a starfish cut away to show the pyloric cæca, or hepatic lobes.

Nearly filling the cavity of each arm is a pair of long, brownish appendages, the *pyloric cæca* (Fig. 44). The pyloric cæca have glandular walls, and as they secrete a digestive fluid are to be looked upon as digestive glands. Each pair is connected by a single tube with the pyloric division of the stomach and empties its secretions into this part of the stomach.

The food of the starfish and how eaten. — The starfish lives upon crustaceans and mollusks, especially oysters. When a starfish attacks an oyster, its body is arched over the latter, and the stomach is extruded through the mouth

and wrapped around the victim, which is then dissolved and digested, after which the stomach is withdrawn into the body.

The water vascular system. — The madreporite, of which we have already spoken, is the cover to a short canal, the *stone canal,* that runs downward and opens into a ringlike canal that encircles the mouth. Five long canals, one for each arm, radiate from the ring canal about the mouth. Each of these long radiating canals is provided with many short side branches to which are attached the tube feet (Fig. 45). Each tube foot is connected, by a slender tube that passes through a minute pore between the ossicles, with a water bulb in the body cavity. The bulb and the tube foot are both contractile.

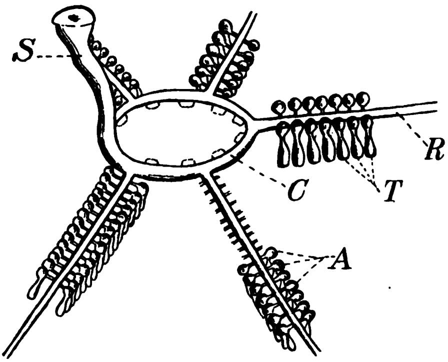

Fig. 45. — Diagram of the water vascular system of a starfish: *S*, stone canal; *C*, circular canal; *R*, radial canal; *T*, tube feet; *A*, ampullæ. After Brooks.

This whole system of tubes is called the water vascular system (Fig. 45). The tubes are filled with a watery fluid composed largely of sea water that flows in through the madreporite.

Locomotion of the starfish. — When the starfish desires to move, it compresses the water bulb connected with each tube foot and forces the water out into the latter organ. This greatly elongates each tube foot which is then directed forward in the direction the animal wishes to go. After

being stretched its full length, each tube foot is fastened to some object by the sucker at the end. Then all the tube feet are contracted and the body drawn forward. By a repetition of these acts the starfish progresses over the surface upon which it lies.

The cœlome, or body cavity. — All of the large space within the central disk and arms and between the alimentary canal and body walls is called the *cœlome,* or *body cavity.* It is filled with a fluid that consists mainly of sea water but has numbers of amœbalike cells floating in it. This cœlomic fluid is kept in motion by the cilia lining the cœlomic epithelium and thus constitutes a sort of circulation. The nutritive portions of the food are probably absorbed through the walls of the stomach directly into this fluid and are thereby carried to different parts of the body.

How the starfish breathes. — We have already described the branchiæ that project through openings between the ossicles on the dorsal surface. These are now supposed to act like gills in gathering the oxygen from the sea water and are thought to aërate the cœlomic fluid which, in turn, probably carries fresh oxygen to all the organs it bathes.

Nervous system. — Surrounding the mouth is a five-angled nerve ring, from which radiate five nerves, one for each arm. Each of the radial nerves runs along the bottom of an ambulacral groove and may be seen by parting the tube feet along the middle line. At the extreme end of each of the ambulacral grooves is a small, bright red spot, the eye. Over each eye is an organ that resembles a tube foot without a terminal sucker. These organs are called *tentacles* and have been shown to be organs of smell.

Life history and reproduction. — The starfish reproduces

by eggs and the sexes are separate. The ovaries of the female are within the body cavity at the bases of the arms. There is one pair for each arm. The spermaries of the male are in a similar situation. When the ova are mature, they are extruded into the sea through small pores in the body walls at the bases of the arms. In the sea they are fertilized by the sperms and finally hatch into forms very different from the adults. It is also an interesting fact that the young are bilaterally symmetrical. The young feed on microscopic organisms and, as they grow, undergo radical changes until finally they assume the form of the parent starfish.

Other Echinoderms

Not all starfish have just five arms. Indeed, abnormal specimens of the common starfish are sometimes found with four or six arms. But there are some species that normally have more than five arms. One species has as many as thirty. Again, the members of one genus have six arms, an irregular number. Not all starfish are like the one described in regard to the central disk. In some, the disk is more plainly marked off and is more distinct, while in others the spaces between the arms are filled up nearly

Fig. 46. — Ventral surface of a kind of starfish in which the disk extends much farther out than in the common starfish.

to the tips, and it is difficult to tell where the disk stops (Fig. 46).

Brittle stars. — These are starfish that are at once distinguished from those above, by the long, slender, tapering, and cylindrical arms. The central disk is also more sharply marked off from the arms (Fig. 47). Again, there are no grooves along the oral surfaces of the arms, and the tube feet protrude through the sides of the arms instead of through the ventral walls, and are not provided with suckers. Hence, locomotion is effected largely by the slender arms. In some species of brittle stars, the basket stars, the arms are branched many times, producing a complex but beautiful object. Some brittle stars have the remarkable property of being able to throw off pieces of their arms when touched or irritated; hence the name, brittle stars.

FIG. 47. — Brittle starfish. Note that the disk is clearly defined.

Sea urchins. — Sea urchins are common along the eastern coast of the United States, especially where the shore is rocky. They are globular in shape, but with the side, on which the mouth is situated, flattened. These echinoderms have no distinct arms, but the body is bristling with cylindrical, pointed spines jointed to the skeleton so that they are movable (Fig. 48). There are also projecting among the spines, five double rows of tube feet radiating from the

mouth. On removing the spines and skin, a beautiful globular shell (Fig. 49) is exposed, within which are the organs of the body. The shell is composed of limestone plates which fit very closely together and are ornamented on the surface, with rounded protuberances, for the articulation of the spines. The plates composing the shell are grouped together in such a manner that they form ten dis-

FIG. 48. — Sea urchin, showing spines on outside of shell.

tinct zones. Five of these zones bear tube feet and five bear none, and each zone alternates with the other. Therefore, although the sea urchin does not possess five distinct arms bearing tube feet, yet the shell presents five distinct areas bearing tube feet, which is comparable with the structure of the starfish. The sea urchin possesses five long, curved teeth which lie mostly within the body, only the points projecting.

FIG. 49. — Shell of a sea urchin after spines have been removed.

Certain sea urchins, such as the sand dollars, or sea biscuits (Fig. 50), have flat bodies, instead of globular ones. The bodies of others are soft and flexible, wholly unlike that of the common sea urchin.

Sea cucumbers. — Superficially, these echinoderms show little resemblance to a starfish or sea urchin. They are more or less cylindrical in shape and some of them roughly resemble cucumbers in appearance. Some of them have five double

FIG. 50. — Sand dollar, or sea biscuit.

rows of tube feet, and some of them have none. In some there is a distinct ventral side, and in others there is not. They do not have large and closely connected calcareous plates in the body walls to form a continuous skele-

FIG. 51.—Sea cucumber. Note the branched tentacles about the mouth.

ton like that of the starfish and sea urchin, yet their bodies retain a cylindrical shape owing to many very small, loosely connected calcareous plates imbedded in the integument, somewhat like the spicules in the walls of a sponge. The body walls, notwithstanding, are leathery and flexible.

A characteristic feature of the sea cucumbers is the much-branched tentacles about the mouth (Fig. 51). The tentacles vary in number from eight to twenty and sometimes more. These are supposed to be much-modified tube feet, and are used to push food into the mouth. When the animal is disturbed, they can be greatly contracted and drawn completely back within the mouth.

Sea cucumbers vary from two to fifteen inches in length, depending upon the species and the age of the individual. One species of Cucumaria sometimes attains a length of three feet and is orange-red in color.

Feather stars. — This group of echinoderms comprises the lowest representatives and at the same time the oldest members of the branch. The feather stars, crinoids, or sea lilies as they are variously called, are found as fossils in the rocks of the paleozoic age and were very abundant in the past. The living forms are few and, for the most part, inhabit the deeper regions of the sea. It is a characteristic of the crinoids that they are attached to objects in the sea, either for a short period of their life, or permanently. Most of the species are permanently attached to submarine objects by a stem, which frequently is very long, and made up of a series of joints perforated by a central canal. The body (Fig. 52), borne on the end of the stalk, has the oral side uppermost, which position, it will be recalled, is

FIG. 52.—Sea lily.

exactly the reverse of that in the starfish. The arms of the crinoids are often many times branched and the branches bear short, lateral projections called pinnulæ that serve to give the animal a feathery appearance.

Reproduction and development. — The echinoderms reproduce by eggs, not by budding, and the sexes are separate in the majority of species. In one species, at least, the female may be distinguished from the male by a difference in color. In this case the female is decidedly bluish in color while the male is reddish brown and presents a marked contrast to the former sex. The eggs and sperm cells are extruded into the water and there the sperm cells find the eggs and fertilize them. The egg then hatches into a tiny organism, the larva, which has cilia, is free-swimming, and in no way resembles the adult. The larvæ of these animals pass through remarkable changes in their growth to adults and when first discovered, were thought to be distinct species of marine animals and were given various names. For example, the larvæ of sea urchins and brittle stars were called *Pluteus*, while the larvæ of the starfish were called *Brachiolaria* and *Bipinnaria*.

Regeneration of lost parts. — Like the hydra, many of the echinoderms are remarkable for their ability to reproduce parts of the body that may have been broken or thrown off. Certain of the starfish and many brittle stars, when molested, will throw off pieces of their arms or sometimes all of their arms. Indeed it is difficult to obtain these particular species whole. Under these conditions the central disk will produce new arms and sometimes an arm will produce a new central disk and the other arms. Stranger still, in some sea cucumbers a part or even all of the ali-

mentary canal is occasionally ejected from the body and in some cases, at least, becomes completely renewed.

Economic importance of the echinoderms. — In the past starfish have caused much annoyance to oystermen because of the large numbers of oysters devoured by these echinoderms for food. Of late years, however, the oystermen have learned how to keep the oyster beds free, in a measure, from these pests.

Certain species of sea cucumbers are used as food by the Chinese. Great numbers of them are caught on the coral reefs of the Pacific Ocean and China Sea and sold in Chinese ports under the trade name of "trepang."

Relationships and characteristics of the echinoderms. — The echinoderms stand almost alone and without any near relatives. They all have an alimentary canal separate from the body cavity and a well-developed nervous system which place them above all animals so far studied. Without exception they live in the sea, and in all, the parts of the body are radially arranged. Moreover, the parts occur to the number of five or are repeated in multiples of five. This characteristic is well shown by the common starfish which has five arms and by the species of starfish that has thirty arms. Again, the members of this branch possess a water-vascular system and this is eminently characteristic, for no other branch of animals is found with this structure. Unlike the cœlenterates, the echinoderms show no tendency to bud and form colonies of zoöids and the great majority of them are free. They also possess an exoskeleton, which, in some, consists of plates joined together continuously and in others of scattered plates imbedded in the skin. In many the body is armed with spines, hence the name of the branch.

CLASSIFICATION OF THE ECHINODERMS

BRANCH IX — Echinodermata.
- *Class* — Asteroidea.
  - Order — Cryptozonia.
    - Type of Order.
      - *Asterias vulgaris* — Starfish.
- *Class* — Ophiuroidea.
  - Order — Ophiurida.
    - Type of Order.
      - *Ophioglypha lacertosa* — Brittle star.
- *Class* — Echinoidea.
  - Order — Regularia.
    - Type of Order.
      - *Echinus drocbachiensis* — Sea urchin.
- *Class* — Holothuroidea.
  - Order — Pedata.
    - Type of Order.
      - *Pentacta frondosa* — Sea cucumber.
- *Class* — Crinoidea.
  - Order — Neo-crinoidea.
    - Types of Order.
      - *Antedon rosacea* — Feather star.
      - *Rhizocrinus lofotensis* — Sea lily.

XI. MUSSELS, CLAMS, OYSTERS, SNAILS, SQUIDS

Branch X.—Mollusca (*mollis*, soft)

The mollusks are very widely distributed and some of them form an important source of food supply. They are found in the sea, on the land, and in fresh water. Most of them possess very soft bodies which are, in the majority of cases, protected by shells of carbonate of lime. Although the branch, Mollusca, is divided into several classes, we shall discuss only those containing the more familiar forms, represented by the clam, snail, and squid respectively.

An Example of the Branch—the River Mussel

The external features and structure of the shell.—The shell of the mussel is composed of two similar, right and left pieces, or valves. In its natural position, the shell is held vertically with the thin, or ventral edges buried in the mud and the broad, or dorsal edges up. The dorsal edges are joined for some distance by an elastic band, or ligament, the *hinge ligament.* The broad round end of the shell is anterior and the more pointed end is posterior (Fig. 53). Between the dorsal edges of the valves are the projecting hinge teeth that interlock with one another. On each valve, toward the anterior end, is a prominent elevation, the *umbo,* which is the oldest portion of the shell. Additions, marked by concentric rings, have been

made to the ventral edges of the umbo. The shell, which is a calcareous secretion of the outer layer of the mantle, is made up of three layers. The outer layer is a horny, greenish epidermis. The inner layer consists of thin, flat leaves of pearl, the fine sinuous edges of which produce an iridescent effect. The dark middle layer consists of many-sided prisms placed at right angles to the surface of the shell.

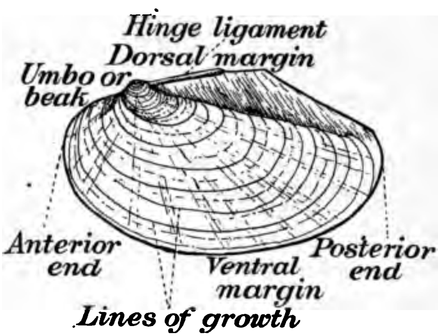

FIG. 53. — Left valve of a clam shell.

Internal features of the shell. — When the body of the mussel has been removed from the shell and all parts carefully scraped away, each valve will present the following features: at the anterior end of the shell the scar of the *anterior adductor muscle* will be seen; at the posterior end, in a similar position, is the scar of the large *posterior adductor muscle;* in close connection with the anterior adductor muscle, are two smaller scars, the upper one, the scar of the *anterior retractor* foot muscle, and the lower,

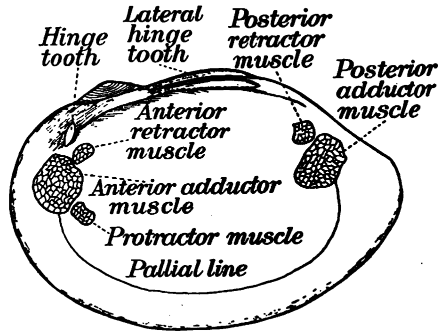

FIG. 54. — Right valve of a clam shell.

the scar of the *protractor* muscle of the foot; just above the posterior adductor muscle scar is the small scar of the *posterior retractor* foot muscle; parallel with the edge of the valve and a short distance from it is a delicate streak, the *pallial line*, that marks the line along which the mantle lobe is joined to the shell (Fig. 54).

How the mussel opens and shuts its shell. — The anterior adductor muscle and the posterior adductor muscle run straight across the cavity between the valves, and their ends are fastened firmly to the inside walls of the shell (Fig. 55). Therefore, when they contract and shorten, the valves are pulled together and held tightly closed. On the other hand, whenever the adductor muscles are relaxed, the strong hinge ligament, which all the time the valves are closed is tightly stretched, throws the shell open by its elasticity. Thus the shell is closed with muscular effort, but is opened by a mechanical, springlike action which requires no effort on the part of the animal. Since the shell is open much more than it is shut, this is a striking adaptation to the mussel's mode of living.

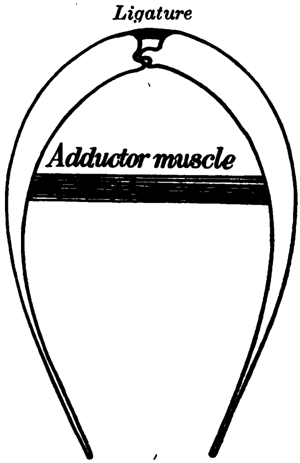

FIG. 55. — Cross section of mussel, showing mechanism of opening and closing.

The mantle and siphons. — Lining the inside of both valves and completely enveloping the body is a soft, white, delicate membrane known as the *mantle.* It really consists of two lobes corresponding to the valves. The ventral edges of the mantle lobes are free and run parallel with the

edges of the valves, but the mantle is fastened, a little ways from the edge, to each half of the shell along the pallial line, already noted. At the posterior end of the shell the mantle forms two short tubes, the *siphons*, which project between the edges of the valves when the mussel rests undisturbed (Fig. 56). In this position a current of water is always passing in through the lower, or *inhalent siphon*, and out through the upper, or *exhalent siphon* (Fig. 56).

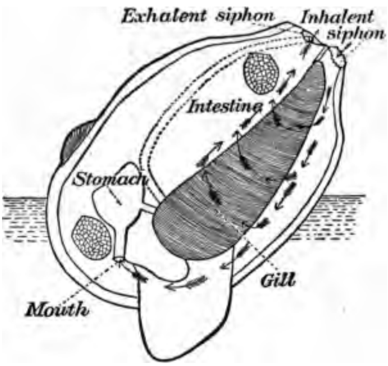

Fig. 56. — Diagram of a clam.

The gills and respiration. — On either side of the posterior part of the body, inside the mantle, is a pair of gills. They hang suspended with the lower edges free and present a ribbed, or striated appearance. Each gill has the form of a V-shaped trough closed at the ends but open on the dorsal side. Running across the trough are partitions dividing it into compartments much like an old-fashioned, wooden pig trough. The sides of the trough are perforated with many small openings, which are lined with cilia. The thin walls of the gills are traversed with blood vessels.

The outer walls of the outer gills are attached to the mantle lobes along the entire length of their dorsal edges, and the inner walls of the inner gills are attached to the sides of the body (Fig. 57). Thus the mantle cavity is divided into two chambers: a dorsal, or cloacal chamber and a ventral, or branchial chamber. The fresh sea water

carrying oxygen is brought into the branchial chamber through the inhalent siphon (Fig. 56). The gill cilia then cause it to flow through the holes in the sides of the gills into the troughs of these organs whence it passes into the cloacal chamber and out through the exhalent siphon. The blood in the gills is separated from the surrounding water by the very thin, membranous walls of the gills, and the carbon dioxide readily passes through this tissue by osmosis, and the oxygen is readily absorbed from the water in exchange.

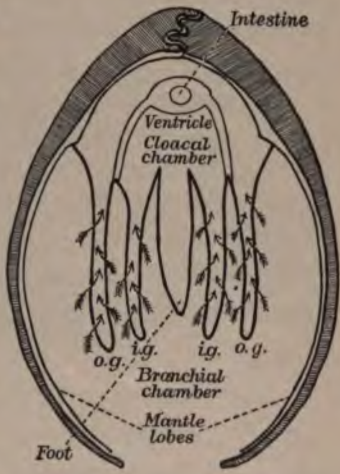

FIG. 57. — Cross section of clam.

The foot and locomotion. — At the anterior end of a living mussel a white, flexible, muscular organ, the *foot* (Fig. 58), is often seen protruding forward and downward between the gaping ventral edges of the shell. This is the organ of locomotion. In its natural position the mussel stands with the anterior end of the shell considerably deeper in the mud than the posterior end. This leaves the siphons clear of the mud and in direct communication with the water above. In this position the mussel plows slowly along through the mud. The foot is slowly extended outward and downward into the mud and anchored there. Then the retractor muscles contract and pull the shell and body up to the foot, as it were. By a repetition of these movements of the foot the mussel covers considerable distances in the course of time.

The alimentary canal and digestion. — The mouth is just under the anterior adductor muscle and between two pairs of soft flaps, the *labial palps*. It leads by a short gullet to the spherical stomach which is surrounded by a dark green mass, the *digestive gland*, or "liver." The intestine passes downward from the stomach, coils once or twice in the abdomen and foot, and returning, runs posteriorly through the ventricle of the heart and ends back of the posterior adductor muscle (Fig. 58). The food, which consists of minute plant and animal organisms, is brought in by the inhalent current, carried to the anterior end of the body (Fig. 56), and directed into the mouth by the cilia of the labial palps. It is acted upon by the fluids from the digestive gland and is absorbed from the stomach and intestine.

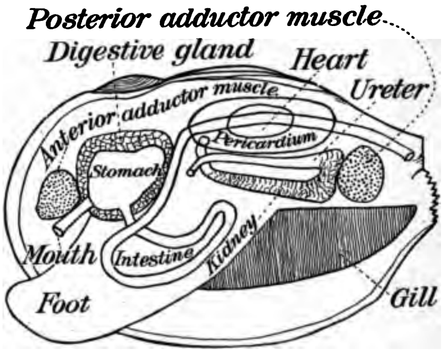

Fig. 58. — Internal structure of a clam.

Excretory organs. — The excretory organs consist of a pair of dark-colored kidneys lying just below the pericardium and in front of the posterior adductor muscle (Fig. 58). Each kidney consists of a glandular portion, the kidney proper, and the whole organ. The urinary tube has two openings, one of which opens into the cavity of the pericardium or sac around the heart while the other opens on the side of the abdomen near the base of the inner gill. It is from the latter, that the excretions of the kidneys are

carried away by the current of water through the exhalent siphon.

The heart and circulation. — The heart is situated in the dorsal part of the body just below the hinge ligament and is surrounded by a membranous sac, *the pericardium.* It consists of one ventricle and a right and left auricle. Two arteries arise from the ventricle, one from the anterior end which passes above the intestine and conveys the blood to the forward parts of the body and another from the posterior end which runs below the intestine and carries blood to the posterior part of the body. By the contractions of the heart the blood is sent out through the arteries into irregular channels that reach all parts of the animal. On its return the blood passes first through the kidneys, where it gives up nitrogenous waste matters. Then it flows to the gills, where it is aërated, and finally, from the gills, it passes directly into the thin-walled auricles. These open into the ventricle. Thus the blood reaches its starting point, having completed the circuit of the body.

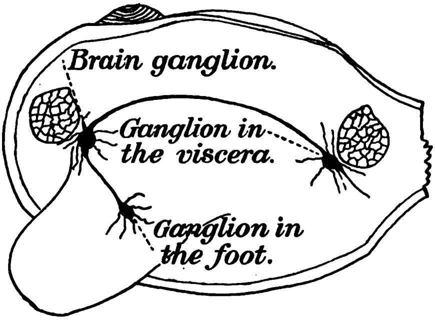

Fig. 59. — Part of nervous system of a clam.

The nervous system. — This system consists of three pairs of ganglia with their radiating nerves. Two ganglia, just above the mouth, one on each side of the gullet, form the brain. They are connected by a nerve cord running above the gullet. From the brain a nerve cord runs posteriorly along each side of the body and joins a pair of visceral

ganglia just under the posterior adductor muscle. Finally, a pair of pedal ganglia is buried in the tissues of the foot near its base. Each of these is joined to the brain ganglion on the corresponding side by a nerve cord (Fig. 59). These different pairs of ganglia send nerves to all the adjacent parts.

This system of nerves gives sensation to all parts of the body. The senses are not acute, but touch is well developed, especially in the point of the foot and margin of the mantle and around the edges of the siphons. There is no positive evidence that the mussel can taste or smell and it cannot hear, but it can *feel* vibrations through the soil or water.

Reproduction and life history. — The sexes are separate and may sometimes be distinguished by the greater convexity of the shell of the female. The ovaries and spermaries are similar in appearance and are situated around and among the coils of the intestine. The ducts from both open on the side of the body near the openings of the urinary tubes. The sperms enter the shell of the female in the incoming currents of water and fertilize the eggs. The eggs then drop into the troughs of the outer gills, which serve as brood pouches and retain the eggs until they hatch. The embryo mussels are called *glochidia* and have soft bodies inclosed by two triangular valves. Each glochidium finally passes out through the exhalent siphon and rests, for a time, on the bottom, when it attaches itself to some fish by the lower hooklike projections of the valves and leads a truly parasitic life for two months, after which it undergoes a metamorphosis and falls to the bottom again, there to begin an independent existence.

Distribution and economic importance. — This mollusk is widely distributed in the fresh-water streams and lakes

of the United States. The pearly layers of its shells furnish material for large quantities of buttons, and pearls of considerable value are often found within its shells. According to recent investigations, it has been shown that pearls, at least in the mussel, result from the irritation caused by the presence of a minute roundworm parasite in the mantle of this mollusk. The larva of this parasitic worm, essaying to bore through the mantle, rests for a time among the loosely connected cells of the latter. As a result, the cells of the outer layer of the mantle are stimulated to deposit a hard substance, called *nacre* around the resting larva. This nacre, owing to the fine ridges running across it, produces an iridescent object which we call a pearl. It is now thought that all pearls are formed in this way, although it was formerly held that an undeveloped egg or grain of sand lodging between the shell and mantle would stimulate the latter to deposit nacre and thus form a pearl.

The mussel is protected from its chief enemies, the raccoon, mink, and otter, by remaining on the bottom partly hidden in the mud and by withdrawing into its hard calcareous shell.

XII. CLAMS, OYSTERS, AND MUSSELS

MOLLUSCA (*continued*)

Class I.—Pelecypoda (*hatchet-footed*)

THE clams, oysters, and mussels belong to this class. The bodies of all are soft and inclosed in a bivalve shell.

Clams. — Perhaps the two species of clams best known because most eaten are the long clam (Mya) and the round clam (Venus). The round clam, also known as the "quahog," "little neck clam," etc., is characteristic of the warmer waters. It is common on sandy shores and on muddy flats, just beyond the low-water mark, from Cape Cod to Texas. It burrows a short distance below the surface, but is often found plowing at the surface with its shell partly exposed.

On the other hand, the long clam, or soft-shell clam, is an inhabitant of cooler waters and extends north to the British Provinces, although it overlaps and extends into the territory occupied by the round clam. The long clam is remarkable for the length of its siphons. These constitute the so-called "head," or "neck" and can be extended from three to four inches beyond the valves of the shell (Fig. 60). When quite young, the long clam begins a burrow in the mud and keeps on enlarging and deepening it as it grows older, until the clam may finally reach a point eight or ten inches below the surface. While lying at the bottom of this burrow, the long siphons are extended up to the surface of

the mud within reach of the sea water. In this position a stream of sea water carrying food and air goes down one tube, is driven through the gills, and finally back up the other tube to be poured into the sea above.

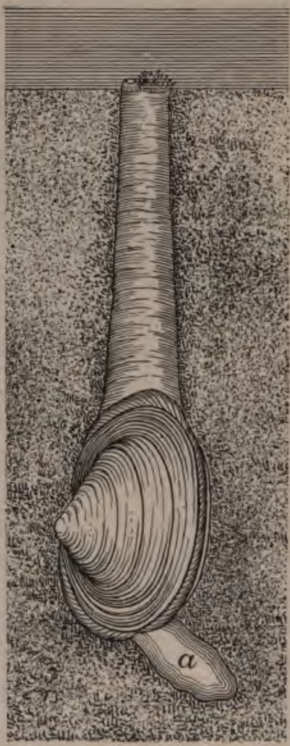

FIG. 60. — Long clam in its burrow.

Oysters. — They are similar in structure to a mussel, except that they have no foot, or only a rudimentary one, and no siphons, and the valves of the shell are unequal. One valve is hollowed out to receive the body of the oyster, and the other valve is nearly flat. Usually the hollow valve is attached to some submerged object. They live all along the Atlantic coast south of Cape Cod, and along the Gulf coast. Oysters are, probably, most extensively grown in the Chesapeake Bay. Their eggs, which are produced in great quantities, soon hatch, and, after a few days of a free-swimming life, the young oysters attach themselves to some objects, usually old shells, and begin growing in earnest. It takes an oyster from three to five years to become of marketable size. In making artificial beds, old shells, pieces of earthenware, and slate are thrown into the water for places of attachment for the oysters. Oysters live on minute plants and animals found in fresh

sea water. It is necessary that they have plenty of fresh sea water and food, and that the mud does not settle over them, else they will smother.

About Ceylon and Australia, in the Persian Gulf, around the Philippines, Panama, West Indies, etc., is found the true pearl oyster. The American form, which averages about nine inches across, is somewhat smaller than the Old World form, for the latter often becomes a foot in diameter. Pearl fisheries are carried on in many different parts of the world, but the most extensive ones are in Ceylon while the finest pearls are said to be found in the Persian Gulf.

The teredo, or ship worm, is a mollusk of strangely modified form and interesting and unusual habits. It bears very little resemblance to a bivalve mollusk, for its body is long and wormlike in appearance, although it has a small bivalve shell at one end and two long siphons at the other. The embryonic teredo is ciliated and free-swimming like the oyster, but instead of settling on some object and simply attaching itself, it finds a submerged piece of wood,—for instance, the bottom of a ship or piles of a wharf,—and begins to burrow into this wood. As it grows, it burrows deeper and deeper and lines its burrow with a calcareous deposit. When a large number of these small mollusks attack the piles of a wharf or the bottom of a ship they fairly riddle them with holes a foot or more in depth and cause much damage.

Snails, Slugs, and Seashells

Class II.—Gasteropoda (stomach-footed)

To this class belong the snails, slugs, etc. The snails have a shell composed of a single piece, while the slugs have

no shell or only a rudimentary one. A head bearing eyes and tentacles is present, and the foot forms a large flat disk with which the animal creeps over the ground.

FIG. 61.—Pond snail (*Limnæa*).

Snails.—The pond snails, Physa and Limnæa, are common examples of fresh-water snails. Their habits are much alike. Each has a spirally coiled shell (Fig. 61) and each breathes air directly, by coming to the surface of the water and taking the air in through a tube, the opening of which is just within the edge of the shell. These snails are vegetable feeders, living upon bits of water plants rasped off with a long, flat, fleshy band, or ribbon, situated in the mouth. This band is beset with sharp teeth and is known as the *lingual ribbon*. The flat, triangular portion of the body, by means of which the snails move, is the

FIG. 62.—Pond snail (*Physa*): *a*, foot; *m*, mouth.

foot (Fig. 62). The head bears two feelers, or tentacles, and a pair of eyes.

Physa lays its eggs in February or March, in bean-shaped, transparent, gelatinous masses, on leaves or sticks in the water. Limnæa lays fewer eggs in a mass, and lays them later in the spring.

Besides Limnæa and Physa, the snails that belong to the genera Planorbis and Paludina are commonly known as "pond snails." The members of the former genus have shells coiled in a flat spiral, like a roll of tape, and breathe air directly, like Limnæa. The members of the latter genus have, generally, a longer and more pointed shell and breathe by means of gills, much like an oyster.

Helix. — The common garden snail will serve well as an example of the genus Helix (Fig. 63). It has a horn-colored shell within which it can contract the whole body. It has two eyes, one at the end of each of the large tentacles. It breathes by means of a lung which communicates with the outside by an opening in the side of the snail's neck that can be closed or opened at will. This snail lives on plants. In France, some members of the genus, Helix, somewhat larger than our own garden snail, are extensively eaten as food.

FIG. 63. — Garden snail.

Slugs. — These are snails that have no visible shell, — in fact, some of them have none at all. They usually feed only in the night time, hence are not often seen. One, which is sometimes found crawling along roads or walks, is known

as Limax (Fig. 64). It is dark in color, with two large tentacles on its head, and if looked at closely, will be found to carry a dark, fleshy cape, the mantle, just back of the head. Some slugs leave a white, shining streak wherever they go, owing to the fact that they give out a mucus which hardens in the air. This is done to make a soft silky path over sand and ashes or other harsh substances that would irritate the body. They may be traced long distances and up

FIG. 64. — Slug (*Limax*) : *o*, opening to the lung; *c*, mantle.

trees, by this shining streak. When ready to descend from the trees, some species spin out a thread of the mucus, like a spider, and drop down by means of it, instead of retracing their path. They often occur in such numbers as to be injurious to garden vegetables.

Sea slugs. — There is a group of marine mollusks, known as the nudibranchs, that have no shells in the adult stage, hence are often called sea slugs or naked mollusks. The gills of these mollusks are usually arranged in tufts that project from the sides or back of the animal. The sea slugs are of various and striking colors, and vary greatly in shape

and size. They are usually found creeping on hydroids or upon the seaweeds along the shore.

Seashells. — The so-called "seashells" are the shells of snail-like mollusks that live in the sea. The shells of these mollusks are of many different shapes, colors, and sizes. The cowries are favorites with collectors. The little oval, sharp-spired periwinkles are common along the seacoast. Others of these mollusks have very long, slender, many-whorled shells.

Squid, Cuttlefish, and Octopus

Class III. — Cephalopoda (head-footed)

As the name indicates, these animals, which include the squid, cuttlefish, octopus, etc., have footlike appendages on the head. The appendages are really used for grasping, and are called tentacles, or arms. Sometimes a shell is present, and sometimes it is not. When present, the shell is usually internal; but, in the nautilus, the shell is well developed and external.

The squid. — The body of the squid is long and slender and incased in a thick, fleshy mantle in lieu of a shell (Fig. 65). On each side of the body, at the posterior end, is a triangular fin used to guide the body in swimming. The head is distinct, bears two prominent eyes and five pairs of arms or tentacles, all furnished with cuplike suckers for grasping its prey. One pair is usually longer than the others, and each member of this pair is expanded near the end where it bears four rows of large suckers. The mouth is in the center of the cluster of arms at their bases and has two strong, horny, black jaws like the beak of a parrot. Inside the body is a sac containing black pigment which is

used as a means of defense. When pursued by an enemy, the squid ejects some of this pigment which colors the water and blinds the pursuer.

FIG. 65. — Squid.

The body of the giant squid sometimes becomes eight or nine feet long, while the largest pair of arms may attain a length of twenty or thirty feet.

Cuttlefish.—The internal shell of this animal is calcareous and furnishes the cuttle bone so universally used for feeding canaries. The body of a cuttlefish is much shorter and more oval than the squid's. Otherwise these two mollusks are much alike. It is from the cuttlefish, *Sepia*, that the pigment is obtained from which sepia ink is made. See Figure 66.

Octopus. — The body of the octopus is more or less egg-shaped, and usually not large. A species on the Pacific coast is sometimes found with a body one foot long, six inches in diameter, and with arms twelve to fourteen feet

in length. The octopus, as its name indicates, has eight arms, all of which are provided with suckers. Although many thrilling tales have been written about the devilfish, or octopus, not one authentic account has been given of actual harm done to man by this creature. In fact, it seems to be rather timid in its natural haunts, retreating from the presence of man. Its food consists almost entirely of crabs, clams, etc. The octopus is eaten as food by some of the people about the Mediterranean.

FIG. 66.—Cuttlefish.

Pearly nautilus.—This member of the Cephalopoda has a well-formed shell coiled in a flat spiral. The interior of the shell is divided by partitions into chambers. The animal itself occupies the large outer chamber; and the only communication it has with the other chambers is by means of a long tube, the *siphuncle*, which pierces the center of each partition and extends through all of them to the tip end of the shell. The pearly nautilus is the only surviving member of a large group, the ammonites, that lived during past ages of the earth's history. The shells of the pearly nautilus are common (Fig. 67), but the animals themselves

are rare. Oliver Wendell Holmes has made "The Chambered Nautilus" the subject of one of his finest short poems.

Characteristics and relationships of the mollusks. — All of the members of this branch have soft bodies. With the exception of the slugs, squids, cuttlefishes, and a few others, their bodies are protected by shells which are usually composed of one or two valves. The majority of mollusks live in water and breathe by gills. Some breathe air directly by means of lungs.

FIG. 67. — Shell of pearly nautilus.

It is thought that the branch Mollusca is more closely related to the Annulata than to any of the preceding branches. It is certain that they are the highest animals so far studied.

Adaptations to environment. — Perhaps the first adaptation to note is the unique one which enables the long clam to live so deep in the mud, out of reach of its enemies above. There it lies six or ten inches deep in the mud, and yet, by means of its long siphons, is able to get a supply of fresh air, water, and food.

Although the squids have no outside shell for protection, they have a sac full of pigment by which they can color the water, blind the pursuer, and so escape.

The lung of the pond snail, besides acting as a lung, serves

also as a means of varying the specific gravity. If a snail floating at the surface of the water be touched, the lung will force out a bubble of air, thus causing its body to sink quickly out of the way of danger.

The slug has the power to spin a path of silk to protect its body from irritating substances. The silk also serves as a means of traveling; for example, when the slug is descending a tree.

Economic importance of the Mollusca. — This is probably the most important group, economically, that has been discussed. The class containing the clams and oysters stands first in economic importance. The oyster industry is carried on in nearly every seacoast town and village from Massachusetts to Texas. The industry reaches its highest development in Chesapeake Bay and vicinity. The business gives employment to thousands of persons, and the value of the oysters sold amounts to millions of dollars annually.

Mention must be made of the products obtained from the pearl oyster. It annually furnishes large quantities of valuable pearls, and the mother-of-pearl obtained from the shells of this mollusk forms, in the aggregate, a product of great value. Buttons, knife handles, penholders, umbrella handles, etc., are made from mother-of-pearl. Mention has already been made of the economic importance of the fresh-water mussel. The clams, periwinkles, and some snails form a considerable source of food supply. On the other hand, the shipworm does great damage by boring into piles, wharves, and ships. The slugs often become injurious in gardens, but the squid is of value for cod bait while the cuttlefish furnishes cuttle bone and the material for sepia ink.

CLASSIFICATION OF THE MOLLUSCA

BRANCH X — Mollusca.
- *Class* — Pelecypoda.
  - Order — Pseudo-lamellibranchia.
    - Types of Order.
      - *Ostrea virginiana* — Oyster.
      - *Meleagrina margaritifera* — Pearl oyster.
  - Order — Eulamellibranchia.
    - Types of Order.
      - *Unio complanata* — River mussel.
      - *Mya arenaria* — Long clam.
      - *Venus mercenaria* — Quahog, or Round clam
- *Class* — Gasteropoda.
  - Order — Pulmonata.
    - Types of Order.
      - *Physa species* — Pond snail.
      - *Limnæa species* — Pond snail.
      - *Planorbis species* — Pond snail.
      - *Paludina species* — Pond snail.
      - *Helix albolabris* — Land snail.
      - *Limax flavus* — Slug.
- *Class* — Cephalopoda.
  - Order — Decapoda.
    - Types of Order.
      - *Loligo vulgaris* — Squid.
      - *Sepia officinalis* — Cuttlefish.
  - Order — Octopoda.
    - Type of Order.
      - *Octopus vulgaris* — Octopus.

XIII. CRAYFISH, LOBSTERS, SPIDERS, AND INSECTS

Branch XI. — Arthropoda (*arthron*, joint; *pous* (*pod*) foot)

Like the earthworms and leeches, the members of this branch have segmented bodies. In addition to this, many of these segments bear appendages of various kinds that, in turn, are segmented; for example, the legs of insects. Such appendages mark a decided advance over the worms. The branch is very naturally divided into five classes, only four of which we shall discuss here. These four classes are represented by the lobsters, spiders, centipeds, and insects respectively.

An Example of the Branch — the Crayfish

The form and divisions of the body. — The crayfish has a long, rather thin body, convex above but concave on the ventral surface. It is covered, externally, by a hard, calcareous crust that protects the organs and furnishes places of attachment for the muscles. The body is divided into two regions: the anterior region, or *cephalothorax*, and the posterior region, or *abdomen* (Fig. 68). The cephalothorax is made up of the head and thorax closely joined and is covered above and on the sides with a hard, shieldlike structure known as the *carapace*. A transverse groove, the *cervical suture*, on the surface of the carapace, separates the head from the thorax. The abdomen is plainly divided

into segments similar to the body of an earthworm. The cephalothorax is also segmented; but the segmentation is obscured on the dorsal surface by the carapace, but shows plainly on the ventral side.

Fig. 68. — Crayfish.

The appendages of the abdomen. — Each segment of the abdomen (in the male), except the last, bears a pair of appendages known as the *swimmerets*. These are small, segmented, leg-like organs held close under the abdomen, with the exception of the last pair. These are broad and flat, and, together with the last segment of the abdomen, the *telson*, form the tail fin, or swimming fin. In the female, the first two pairs of swimmerets are either very small or altogether lacking.

Appendages of the cephalothorax. —The appendages of the cephalothorax may be divided into five groups: the walking legs, five pairs; the foot jaws, or *maxillipeds*, three pairs; the jaws, two pairs of maxillæ and one pair of mandibles; the antennæ, or feelers, one pair; and the antennules, one pair.

The walking legs are attached to the thorax and each

one is composed of several segments which permits freedom of movement. Each of the first pair of legs terminates in a large pair of *forceps*, or *pincers* for grasping. Just anterior to this pair of legs are the three pairs of foot jaws. These cover the mouth and aid in crushing the food. The next three pairs of appendages constitute the jaws. The first pair, the *mandibles*, are short, hard, and toothed and grind the food. The two following pairs are small, soft, and weak, but each member of the second pair carries a curved, paddlelike plate, the *gill scoop*, that performs an important function in respiration to be explained later. On the front of the head are the two long antennæ. Above each antenna is a forked appendage, the antennule.

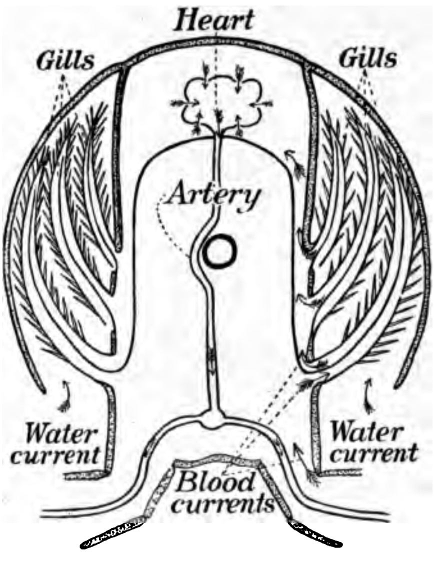

FIG. 69. — Cross section of crayfish.

The situation, form, and attachment of the gills. — That part of the carapace covering the thorax is plainly divided into three pieces, a narrow middle piece and two wide side pieces that arch downward and cover the sides of the thorax. Beneath these two large side pieces are two long chambers containing the gills. The gills are borne in two sets, an upper set and a lower set. The lower set is attached to the basal seg-

ments of the legs and maxillipeds. The upper set is attached to the membranes that connect the thoracic appendages to the thorax. Each gill is plumelike in form with a stem and feathery side branches, and stands vertically with the free end pointing upward. In the stem are two blood vessels, one for the entrance of the blood and one for its exit (Fig. 69).

The locomotion of the crayfish. — The crayfish has two methods of locomotion, walking and swimming. It walks with the four posterior pairs of legs, holding the first pair, which bears the claws, out in front. The crayfish, at best, walks rather clumsily and usually slowly. The water aids in buoying up the body, for on land this crustacean walks more awkwardly still and the body bumps over the ground with evident annoyance.

In swimming, the broad tail fin is spread out as wide as possible and the powerful muscles of the abdomen contract very quickly and pull the tail with a sudden downward and forward stroke beneath the abdomen. This action, of course, always forces the crayfish in a backward direction. It swims rapidly, and as the animal usually remains close to the bottom, the body and dragging legs invariably stir up a cloud of sediment that hides the animal from its pursuing enemies. In this backward swimming of the crayfish the unwieldy claws are prevented from retarding the rapidity and celerity of its progress by being dragged unresistingly after the body.

The alimentary canal. — The mouth, which is situated in the middle of the ventral surface of the head, opens into a short gullet that leads directly upward to a large, capacious stomach (Fig. 70). The stomach, situated in the head, is divided by a constriction in the middle into two

portions, a *cardiac division* and a *pyloric division,* similar to the stomach of a starfish. The pyloric division opens into the intestine, which runs almost straight to the anal aperture on the ventral side of the telson. The pyloric division of the stomach is surrounded by two pairs of large digestive glands (Fig. 70), often called "livers," that open

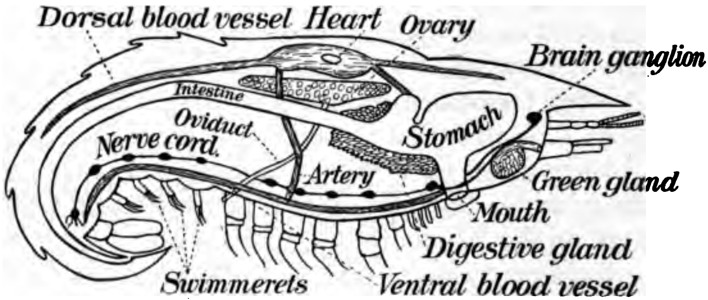

FIG. 70. — Structure of a crayfish.

through short ducts into the anterior end of the intestine. The stomach is lined by a chitinous layer, and projecting from its inside walls are several dark brown, chitinous teeth. Strong muscles also run from the outside of the stomach to the walls of the body.

The food and digestive process. — The food of the crayfish consists of both plant and animal matter, preferably the latter. These animals sometimes destroy vegetables in gardens, but their diet consists chiefly of worms, snails, and insect larvæ. The crayfish is also a scavenger and devours dead fish, clams, and other substances that might pollute the water. They sometimes eat their own cast skins, the shells of snails, and occasionally, each other. Sometimes the food is gnawed off directly by the mandibles, and sometimes it is torn off in bits by the large pincers and

passed into the mouth by the small pincers on the walking legs.

The food is partly masticated by the mandibles, maxillæ, and foot jaws. It then passes into the stomach, where it is farther comminuted by the churning action of the chitinous walls aided by the chitinous teeth. The stomach is really a masticating organ and has no digestive function.

As soon as the food leaves the stomach, it receives the fluids from the digestive glands and the work of digestion takes place at once in the anterior end of the intestine. The food then passes through the walls of the intestine directly into the blood which distributes it all over the body.

The circulatory system. — The circulation of the crayfish is well developed. The heart (Fig. 70) is situated in the dorsal part of the thorax. Five arteries originate from the anterior end of the heart. One goes forward to the eyes, two (paired) supply the antennæ, antennules, and stomach with blood, while two (paired) furnish blood to the digestive glands. From the posterior end of the heart two single arteries spring, one of which, the *dorsal artery*, passes backward along the dorsal side of the intestine and furnishes blood to the intestine and dorsal muscles through many branches. The other passes directly downward and joins the *ventral artery* which runs lengthwise of the body below the nerve cord (Fig. 70). The ventral artery sends branches to the legs and abdominal appendages and muscles. All of these arteries divide and subdivide into smaller and smaller branches until they end in microscopic vessels called *capillaries*. The capillaries empty the blood into irregular spaces, or *sinuses*, that occur all through the body between the muscles and other organs. These sinuses communicate

either directly or indirectly with one large sinus, or canal, that runs along the middle of the thorax and abdomen below the intestine. From the anterior end of this large sinus tubes conduct the blood to the different gills. Here, the blood is carried in one tube to the gill filaments, where it is aërated and returned through the other gill blood vessel to a set of veins, the *branchio-cardiac veins*, that lead to the pericardium, a sac surrounding the heart. Finally then, the blood which was sent out from the heart is returned and poured into a cavity, in the middle of which lies the heart. The blood now flows directly into the heart through six simple openings in the walls of this organ. The holes are all provided with valves on the inside that prevent the return of the blood when the heart contracts. Therefore, the beating of the heart sends the colorless blood all over the body and brings it back again in a continual flow.

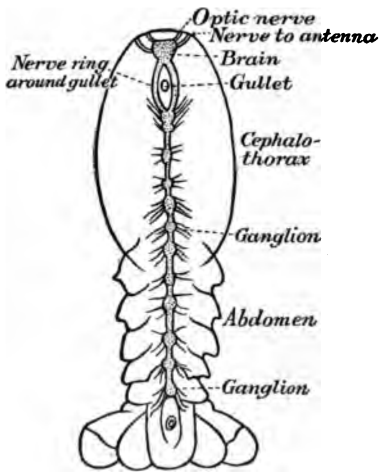

FIG. 71. — Nervous system of a crayfish.

The nervous system. — The nervous system is quite similar to that of the earthworm (Fig. 71). It consists of a brain formed from the fusion of three pairs of ganglions and situated in the head anterior to the stomach. A double white nerve cord extends from the brain along the floor of the thorax and abdomen. As in the earthworm, so in the crayfish, the cord passes on the

right and left sides of the gullet and forms the *nerve collar*. The cords afterward join and become closely fused and studded with ganglia in the thorax and abdomen. Many of the ganglia have become fused so that there are only thirteen distinct ganglia for the twenty body segments. From the ganglia nerves pass to all the organs of the body.

Senses of the crayfish. — The crayfish has the sense of sight, touch, smell, and perhaps taste.

Each of the two large eyes, which are compound, is made up of a number of small, square areas, or *facets*, and is borne on the end of a movable stalk. The stalks are extensible and can protrude the eyes or withdraw them out of the way of danger. In addition, each stalk "is muscular and capable of turning the eye, when protruded, to look in any direction."

There are a number of stiff hairs, or setæ, on the external branch of each antennule that are supposed to be the seat of the sense of smell.

There is also a sac in the basal segment of each antennule that is in free communication with the surrounding water. Formerly these were supposed to be organs of hearing but are now known to be balancing organs. These aid the animal in maintaining its equilibrium.

The sense of touch is widely distributed over the body, although through such a thick crust it is probably not very acute. The antennæ, however, are delicate organs of touch.

Respiration of the crayfish. — The plumelike gills are the organs of respiration. In the filaments of the gills the blood is separated from the surrounding water by a very thin membrane and the carbon dioxide readily passes through this tissue by osmosis and the oxygen is as readily absorbed from the water in exchange. The gill scoops,

which were described as paddlelike organs attached to the second maxillæ, play back and forth in the anterior openings of the gill chambers and propel the water forward out of the chambers. This causes the fresh water, bearing oxygen, to flow into the chambers from below, thus producing continuous currents over the gills.

Method of excretion. — The carbon dioxide, as we have just noted, is given up by the blood in the gills. In addition, there are two green-colored excretory organs, the so-called green glands, situated in the head, just in front of the stomach. Each organ consists of a cushion-shaped gland and a thin-walled sac, or urinary bladder, that opens to the exterior by a duct which has its mouth on the ventral side of the basal segment of the antenna.

Reproduction and life history. — The sexes are separate and the abdomen of the female is much broader than that of the male. The ovary is situated above the anterior end of the intestine and below the heart. The eggs are laid the last of March or in April, at least in the central states, and are glued by the female to her swimmerets. The eggs are small, spherical, and dark colored and adhere to the swimmerets in berrylike clusters. After some weeks the young crayfish issue from the eggs but remain attached to the swimmerets for some time. They attain a length of about an inch and a half the first season, but during the later years grow more slowly and rarely become over five or six inches long.

Regeneration of lost parts. — The large legs of the crayfish are often lost in fighting and sometimes the legs are broken off when the body is being pulled out of its old skin. In either case, new ones will readily grow out again. When a leg is broken off, the blood quickly coagulates at the broken

surface, thus stopping more flow and the wound soon heals. A crayfish with one claw smaller than the other is occasionally found. The smaller claw is simply replacing one that has been lost.

Habitat and habits. — Crayfishes are widely distributed over the United States except in parts of New England and may be found in most ponds, creeks, rivers, lakes, and in many springs. Some species live in holes dug deep enough to reach water or, at least, considerable moisture. One of these burrows, traced to its bottom in digging a mine shaft, extended straight downward for twenty-six feet.

Some of the burrowing species build mud chimneys about the entrances to their burrows. Those that live in water usually remain close to the bottom, where they hide during the day beneath stones, sticks, or plants.

Methods of protection. — The crayfish often escapes from its pursuer in the cloud of sediment stirred up in its movements. In addition, the great pairs of claws are very efficient organs of defense against its lesser enemies, at least. Moreover, it lives near the bottom where there are many places in which to hide and its threatening attitude, when hard pressed, must often frighten its enemies away. Finally, the body varies a good deal in color and blends so nicely with surrounding objects that it is hard to distinguish.

Molting of the crayfish. — During the growth of this animal it sheds its hard, thick covering from time to time. It is evident that the body cannot expand when confined in such an unyielding investment, and special provision has been made for growth by casting off, or molting the hard, limy skin. Before molting, a new soft skin is formed beneath the old one. When ready to molt, the carapace splits along the middle line of the dorsal surface, and the

cephalothorax, great claws and all, is drawn out of the old skin. Many times a good deal of difficulty is experienced in pulling this part of the body from the case and the legs are sometimes broken off. Finally, the abdomen is withdrawn and the soft, unprotected body is now free from its old investment. By the absorption of water, the body soon swells to a size much greater than before. This is a critical time for the crayfish, and it hides away in protected nooks until the new skin absorbs lime and becomes hard. In the process of molting, the lining of the gullet, stomach, and intestine is also cast off.

Economic importance of the crayfish. — Crayfishes are used as food to a limited extent in this country and to a considerable extent in Europe. They are also of some benefit as scavengers. In the southern part of the United States they often occur abundantly in cultivated fields and cause serious damage to the growing crops. The levees of the Mississippi River are sometimes weakened by the holes of burrowing crayfishes.

Crayfish, Lobsters, Shrimps, and Crabs

Class. — Crustacea (body inclosed in a crust)

Lobsters. — What has been said about the crayfish, except with regard to distribution, applies essentially to the lobster. Lobsters are found along the Atlantic coast from Labrador to Delaware Bay, and from shallow water to a depth of one hundred fathoms. They reach their greatest size on the rocky shores in the cooler waters from Maine to Labrador. They are much prized for food and are caught in traps which are baited with fish offal of which the lobsters are very fond. It is now becoming rare to catch a

lobster weighing more than five pounds, while formerly individuals were common that weighed much more.

Cyclops. — This crustacean is common in pond water aquaria and is large enough to be seen with the naked eye. It is free-swimming and, on account of its rapid, jerky movements, it is called a water flea. The shape of the animal is shown by Fig. 72. The single eye in the middle of the head suggested the name "cyclops." The antennules, which are large, constitute the principal organs of locomotion. The female carries the eggs in sacs attached to the sides of the body.

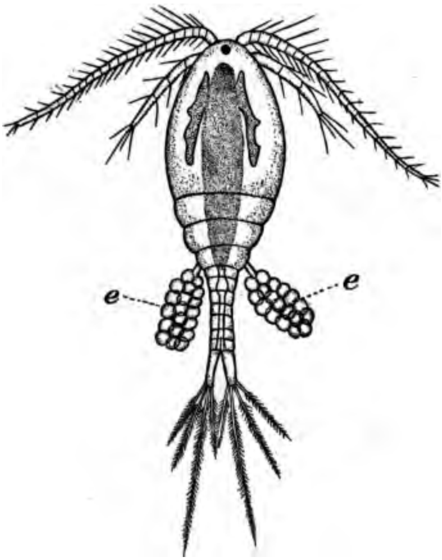

Fig. 72. — Cyclops: *e*, egg clusters.

Barnacles. — These are crustaceans that were formerly thought to be mollusks. They are found in salt water, attached to piles, floating timbers, rocks, etc., and are one of the prominent causes of foul ship bottoms. There are both stalked and sessile barnacles, the former being known as "goose" barnacles and the latter as "acorn" barnacles.

The stalk, when present, is a flexible *stem*, or peduncle covered with a finely wrinkled, dark-colored skin. It bears the body of the barnacle at its free end (Fig. 73),

while the opposite end is firmly attached to some submerged object. The body of the barnacle is inclosed in a sort of bivalved shell which, in reality, is composed of five distinct pieces so arranged that they form two valves, — hence the bivalved appearance, by which the barnacles resemble clamlike mollusks.

The acorn barnacles have no stalk and resemble low, blunt pyramids in form. They are found attached to rocks and piles between tide marks, to ship bottoms, and some species, at least, are sometimes found attached to the bodies of whales. Some species of acorn barnacles grow eight or nine inches in length and are sometimes eaten for food.

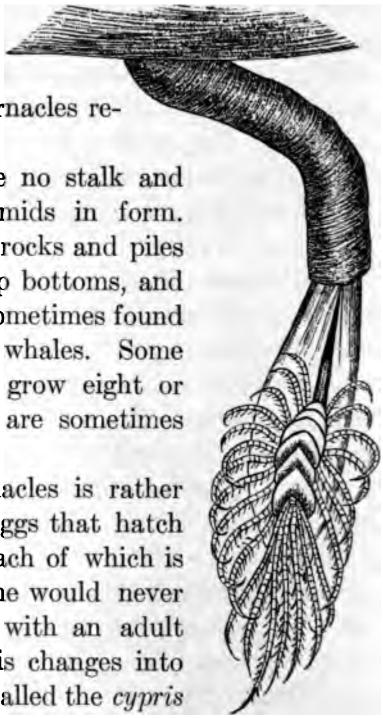

Fig. 73. — Stalked barnacle.

The life history of barnacles is rather complex. The adult lays eggs that hatch into queer little animals, each of which is called a *nauplius*, which one would never imagine to be connected with an adult barnacle. After a time this changes into another and different form called the *cypris* form. Finally this, through successive changes, develops into the adult barnacle. Barnacles are peculiar in having no heart and no distinct blood vessels.

Shrimps. — The shrimps are very closely related to the lobsters and crayfish, and are also of considerable importance as an article of food. The common shrimp occurs in abundance on the eastern coast of North America, from

North Carolina to Labrador, and on the western coast of Europe. It is between two and three inches long, is usually light in color, and is found among weeds or on sandy bottoms in shallow water, but may inhabit water to the depth of fifty fathoms (Fig. 74).

Fig. 74.—Shrimp.

The southern shrimps, or prawns, are found in abundance along the Gulf coast and are sent to the markets of New Orleans, Savannah, Charleston, New York, and Boston.

Hermit crab.—The abdomen of the hermit crab (Fig. 75) is soft, for the skin is not hardened by carbonate of lime; consequently it seeks protection by backing into a deserted shell of some mollusk of appropriate size. When the shell becomes too small by reason of the crab's increase in size, it is abandoned for a larger one. The appendages of the

Fig. 75.—Hermit crab.

FIG. 76. — Crab, from above.

abdomen are very rudimentary except the sixth pair. This pair serves to hold the body firmly in the shell. One of the pincers is larger than the other and both are used to close the mouth of the shell to keep out intruders.

Rock crab. — At first sight this crab resembles a lobster or a crayfish very little. The cephalothorax, which is covered by the carapace, is very broad in proportion to its length (Fig. 76). The abdomen, instead of being long and large, is short, and is permanently curled beneath the head and thorax. In this position it is invisible from above (Fig. 77). Both pairs of antennæ are very small. The first pair of legs bears the great claws for grasping.

FIG. 77. — Crab, from the under side. Note the abdomen.

The life history of this crab is rather com-

plex and interesting. From the egg there hatches a peculiar form, having a long abdomen, few or no appendages, and large compound eyes. This is the larval form and is called *zoëa* (Fig. 78). After molting several times, the larva changes to a form called *megalops* (Fig. 79).

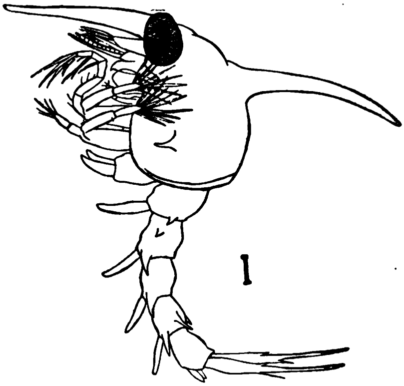

Fig. 78. — Zoëa of a crab.

This form somewhat resembles the adult crab. Finally, the form, megalops, gradually changes, by additional molts, into the adult crab.

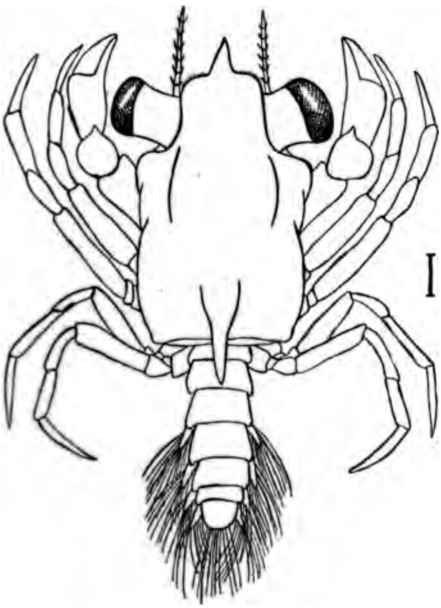

Fig. 79. — Megalops of a crab.

The common blue crab, found along the Atlantic coast from Cape Cod south, and in the Gulf, is our most important edible crab. The so-called "soft-shelled" crabs are simply blue crabs that are caught just after they have cast the old hard skin. The body is then soft and the flesh is considered a great delicacy.

Spider crabs. — The spider crabs are curious-looking creatures (Fig. 80) with their small bodies and long, slender, fragile-looking legs. For the most part they frequent the sea bottom, and their long legs are of great advantage in stalking about over the uneven surfaces that they meet in such a habitat. Some species permit all sorts of foreign bodies, both animals and plants, to become attached to their bodies, so that they are effectually concealed, and

FIG. 80. — Arctic spider crab.

even when moving, it seems as if a small forest of seaweed were being transplanted to another locality. The largest crustacean known belongs to the group of spider crabs. It is the Macrocheira of Japan. Specimens of this spider crab have been caught that measure from twelve to eighteen feet between the tips of the second pair of legs, while their bodies measure only about as many inches in width.

Fiddler crabs. — The fiddler crabs are abundant along the seacoast, especially among salt marshes. They burrow in the sand and have the habit of running sideways to and

from their burrows. One claw of the male is much larger than the other. When these crabs are disturbed, their claws are brandished in an amusing manner, strikingly suggestive of the motions of a violinist, whence these forms have received the common name of fiddler crabs.

Sow bugs.—These are dark-colored, oval-bodied animals with several legs, that live beneath old boards, chunks of wood, stones, etc. They are known as sow bugs (Fig. 81), and wood lice, and feed largely upon vegetable matter, especially upon that which is offensive to man. Some closely related crustaceans, found in the same situations as the sow bugs, can roll themselves up into a ball, and so are called pill bugs.

FIG. 81.—Sow bug. Enlarged.

Regeneration of lost parts.—Like the crayfish, other crustaceans are able to reproduce lost parts. A lobster's claw usually breaks off at a certain point, the "breaking joint," and in the course of succeeding molts will be gradually reproduced. It is thought by some that this is a means of protection, for this breaking adaptation is confined to those appendages which are most apt to be seized, namely, the five thoracic legs. The antennæ of a lobster will also be renewed if broken off. Regeneration takes place in the walking legs of shrimps, crayfish, hermit crabs, etc.

Commensalism.—A certain sea anemone (Adamsia) is sometimes found attached to the shell of the hermit crab. In this position the sea anemone is carried about, and is thus enabled to obtain a more varied and abundant food

supply, while at the same time it affords protection to the crab. These animals then are of mutual benefit to each other, and the sea anemone is the *messmate* or *commensal* (*con*, together; *mensa*, table) of the crab. Such a relation between two animals is called *commensalism.*

The same relation exists between the Hydractinia and the hermit crab. Certain species of sponges "are never found growing except on the backs or legs of certain crabs." This is evidently a case of commensalism, for the sponges conceal the crabs from their enemies and, in turn, are transported to new supplies of food.

Economic importance of the crustaceans. — Many of the crustaceans form an important source of food supply. Many millions of lobsters are taken along the Atlantic coast annually. The value to the fishermen of the lobsters taken off the coasts of the United States is estimated at more than one million dollars. The blue-crab fisheries amount to a product aggregating nearly half a million dollars. Many factories for canning young prawns, which are usually sold as shrimps, are located along the Gulf coast. The shrimp industry of the Pacific coast is very large.

In a discussion of the economic importance of the crustaceans, the smaller forms must be taken into account, for they constitute the principal food of most of our freshwater fishes while young. These minute crustaceans multiply very rapidly and become exceedingly abundant. Large areas of water, hundreds of miles in extent, in the Atlantic Ocean are sometimes colored red by the swarms of these minute organisms. At such times fishes congregate in large numbers to feed upon them, and even whales find that these tiny creatures furnish an abundant food

supply, for their numbers compensate for whatever may be lacking in size.

Chief characteristics of the Crustacea. — They breathe by gills, hence live in the water; they have at least five pairs of legs; the head and thorax are combined into a cephalothorax, and the body is incased in a hard crust formed by the deposition of lime carbonate in the skin.

XIV. SCORPIONS, SPIDERS, AND TICKS

ARTHROPODA (*continued*)

Class. — *Arachnida* (*arachne*, spider)

ALTHOUGH these animals are closely related to the crustaceans, they differ from the latter, in not having their bodies inclosed by a calcareous crust. They differ also in living, with few exceptions, on land. The more familiar examples of this class are the spiders, present everywhere, the ticks, on cattle and dogs, and the mites on fowls and plants.

FIG. 82. — Scorpion.

Scorpions. — Although these animals are thought to be very venomous, it is difficult to find an authentic case of death by a scorpion's sting. The larger species in the tropics, however, cause serious wounds. The body of the scorpion is divided into two distinct regions, the cephalothorax and the abdomen. The abdomen consists of an enlarged portion, next to the thorax, called the *preabdomen*, and a long, slender tail-like portion, the *postabdomen* (Fig. 82). The scorpion has two pairs of jaws and to one pair

are attached two long appendages, ending in claws, that greatly resemble those of a crayfish. Scorpions are found in the southern states and in tropical countries. They are nocturnal in habits, remaining hidden during the day.

Mites. — Unlike the scorpions, these animals have the abdomen joined to the cephalothorax so closely that the body appears as one solid, sacklike piece. The mites are small animals and many of them are parasitic on other animals and on plants. The so-called red spider that lives upon house plants is a kind of mite. The disease known as itch is caused by a minute mite that burrows in the skin. A small mite, called the chicken mite (Fig. 83), occurs at times in poultry-houses and becomes a serious pest.

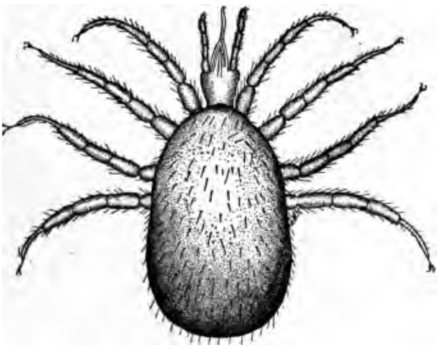

Fig. 83. — Chicken mite. Much enlarged.

Ticks. — The bodies of ticks are like those of the mites, but ticks are usually much larger than mites. One of the most important insects, economically speaking, in the southern states is the southern cattle tick. It is parasitic upon cattle, and is the means of conveying the disease known as Texas fever from one animal to another. When the female cattle tick gets ready to lay her eggs, she drops to the ground from the animal to which she was attached and there lays two or three thousand eggs (Fig. 84). These soon hatch into what are known as "seed" ticks, which eventually find their way to the bodies of cattle roaming

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reputation, but, with one exception, they are harmless and among the most interesting animals in the world.

Spiders have four pairs of legs and two pairs of jaws. At the tip of each one of the larger jaws is a small hole, — the opening of a poison gland through which the poison is

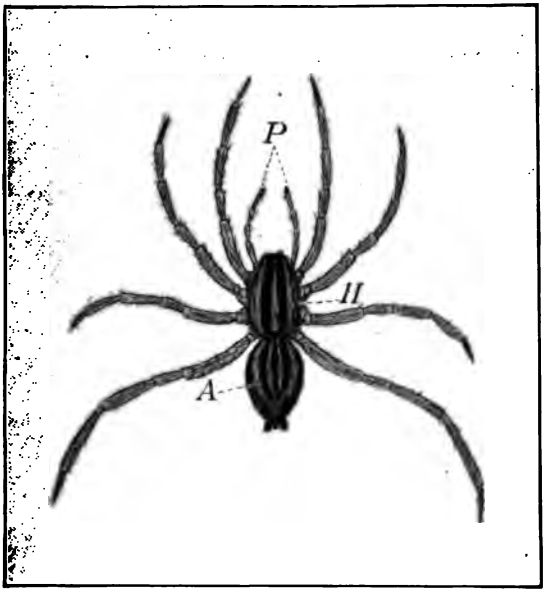

FIG. 85. — **Running spider**: *P*, palpi; *H*, cephalothorax; *A*, abdomen.

..ted into the prey of the spider. Each member of the ..l pair of jaws has attached to it a long, slender ap- ..age called a *palpus* (plural, *palpi*) (Fig. 85). The ..s of spiders consist of two parts, the cephalothorax the abdomen. They may have one, two, three, or .. pairs of single eyes, while certain ones living in caves .. l

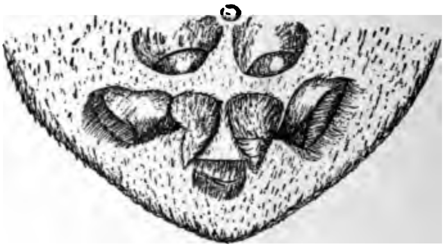

FIG. 86. — Spinnerets of a spider.

The spinning organs (Fig. 86), which are near the posterior end of the abdomen, on the ventral side, consist of four or six finger-shaped projections, called *spinnerets*. On the end of each spinneret are many small tubes called spinning tubes. The substance of which the fine silky thread is made is a fluid inside the spinnerets; but the moment it comes to the air, it hardens and forms the thread. In wrapping its prey a spider spins a band of silk which is usually composed of very many threads.

Spiders spin this silk for various purposes. They make homes of it in which to live, sacs of it in which to put their eggs, traps of it in which to catch their prey, and, finally, they use it as a means of locomotion.

FIG. 87. — Egg sac of spider.

Suspended from bushes and weeds in autumn are found egg sacs like the one in Fig. 87. It is jug-shaped and contains many

FIG. 88. — Orb web. Photographed by J. H. Comstock.

eggs. These hatch early in winter, but no spiders appear until the following spring. During the long winter the larger and stronger of the young spiders devour the weaker

ones so that only the fittest ones survive to become adults in the spring.

Forest paths are often crossed by threads of spider's silk. A spider climbs to the end of a branch and spins out a thread which is caught by the breeze and wafted across the path, where the end becomes entangled in a branch on the opposite tree.

Certain spiders, known as the ballooning, or flying spiders, climb to the end of a post or to the tip of a plant and spin silk into the air which is caught and wafted away by the breeze. When enough is spun to support the spider, it lets go and is borne away by the currents of air. These spiders travel long distances in this manner, as shown by the fact that they have been seen floating through the air at sea far from land.

The spiders that build the irregular webs, termed cobwebs, in dwelling houses belong to the family of cobweb weavers. They are small spiders with very slim legs, and there are many different species of them. By far the larger number live in the fields and spin their webs on bushes.

Those webs spun by the spiders known as orb weavers are marvels of ingenuity and regularity of construction. The webs are common on bushes, fences, weeds, etc. (Fig. 88), but are usually given little attention. The outer framework of supporting threads is often very irregular; but the radiating lines are placed at regular intervals from each other, and the spiral is laid on these in a regular manner.

The radii are dry and inelastic, while the spiral thread is sticky and elastic. Some of the orb weavers spin a zigzag band, or ribbon, across the center of the web, evidently to strengthen it. Many of the orb weavers are small spiders, but some are large. The funnel web weavers spin

their webs upon the grass and the dew often serves to show us what an immense number of these webs are spun.

The trapdoor spiders, found in the southern part of the United States and in other warm countries, excavate tunnels in the soil and line them with silk. Each tunnel is provided with a hinged lid that fits the opening very accurately.

Closely related to the trapdoor spiders are those very large spiders (found in the south and southwest) known as tarantulas. They also dig tubes in the ground which they line with silk. Figure 89 shows one of these tarantulas from western Texas, with its egg sac containing many young tarantulas.

FIG. 89. — Tarantula and egg sac: *A*, mandible.

The members of at least three different groups of spiders spin no webs at all. They catch their prey by running after it or by suddenly jumping upon it. Among these are the common, large, rather hairy spiders that are found beneath boards, logs, etc., and are known as running spiders (Fig. 85);

the crab spiders, so called because they run sidewise like a crab; and the jumping spiders which catch their prey by leaping upon it.

Economic importance of the Arachnida.—The silk of spiders has been utilized to some extent in making cloth; but it is difficult to wind the silk upon a reel, and it is more difficult to rear spiders in sufficient numbers to produce silk in paying quantities. Spiders are of some benefit in destroying injurious insects. Finally, threads of spider's silk are used to form the cross hairs in telescopes and are indispensable for this purpose.

The chicken mite often becomes a serious pest to poultry and undoubtedly causes considerable pecuniary loss by a decrease in the production of eggs and chickens. The pear-leaf blister mite is parasitic upon the leaves of pear trees and in some localities inflicts serious injuries on these trees. Certain species of mites are often very troublesome to house plants, especially in greenhouses. In California, citrus trees are subject to the attacks of a species of mite which sometimes causes severe losses by weakening the vitality of the trees. We have already spoken of the injury caused by the southern cattle tick.

Chief characteristics of the Arachnida.—They have four pairs of legs; the head and thorax are combined into a cephalothorax; they have no antennæ; the eyes are simple, and they do not possess gills but breathe air directly, either through a system of tracheal tubes or by means of lung sacs. Many of the arachnida are provided with glands from which silk is spun. A few, the scorpion, tarantula, and one species of spider in the United States, are more or less poisonous. With few exceptions, they are carnivorous, undoubtedly destroying many noxious insects.

Thousand-legged Worms

Class. — *Myriapoda* (*myrios*, many; *pous* (*pod*), foot)

To this class belong those animals commonly known as thousand-legged worms, because they have so many legs.

Fig. 90. — Centiped from western Texas.

They, of course, are not worms at all, for worms do not have legs. The body, however, is segmented, and most of the segments bear one or two pairs of legs. The head bears a pair of antennæ.

Centipeds. — These animals have a flattened body with one pair of legs on each segment. The head bears a

Fig. 91. — House centiped.

pair of long antennæ (Fig. 90). They occur all over the United States under boards, stones, etc. A common cen-

tiped that is often found in dwellings, especially in the South, is shown in Figure 91. It has long, many-jointed antennæ and fifteen pairs of legs. Some centipeds that live in tropical countries are said to be very poisonous. The poison glands open through the claws of the front pair of legs. The centipeds live on insects, snails, etc. The common one, figured, is harmless to people and does much good by killing cockroaches and other insects that are troublesome.

Millipeds. — These differ from the centipeds in having short antennæ and in having two pairs of legs on all the

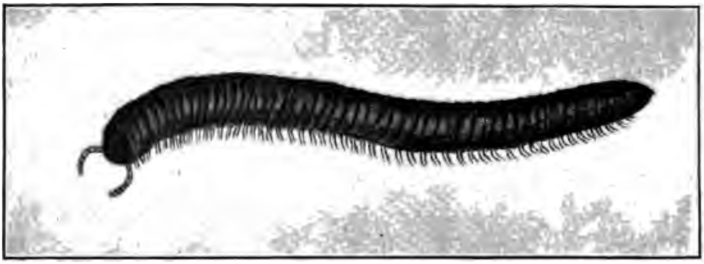

Fig. 92. — Milliped common under decaying logs.

segments of the body except the first three. In most of them the body is more rounded than that of a centiped. The millipeds frequent damp places and, for the most part, feed upon decaying vegetable matter. A certain blind species lives in the Mammoth Cave. Occasionally, some species work injury by eating garden vegetables. Some of them, when disturbed, emit a strong odor from glands opening along the sides of the body. This is evidently a mean of defense. These animals are perfectly harmless to man.

XV.—LOCUSTS, BUTTERFLIES, BEES, WASPS

ARTHROPODA (*continued*)

Class.—*Insecta* (*insects*)

THE number of species of insects is very great and probably exceeds that of any other class in the animal kingdom. They are found in every country in the world. Many species are very injurious to agricultural and horticultural interests, while many are very beneficial to the farmer and the fruit grower. They are exceedingly interesting to study because of their various and peculiar habits. They are also very convenient to study, because they are easily obtained and can be kept in one's room, where every phase of their life history and peculiar habits may be observed.

EXAMPLE OF THE CLASS—THE CAROLINA LOCUST

Distribution and habits.—Insects that are generally known as grasshoppers are really locusts and should be called such. Locusts are widely distributed over the earth and are well-known insects. The Carolina locust is a large insect measuring from one and one half to two inches in length and is common all over the United States and Canada. The male has the interesting habit of poising in the air a few feet from the ground and making a loud, clacking noise, especially during the warmer hours of hot summer days. These locusts (Fig. 93) prefer bare places in fields,

or the hot dusty highways from which they take flight in advance of the rider or pedestrian.

FIG. 93.—Carolina locust. After Lugger.

Segments and regions of the body.—In studying a locust we shall find that its body, especially its abdomen,

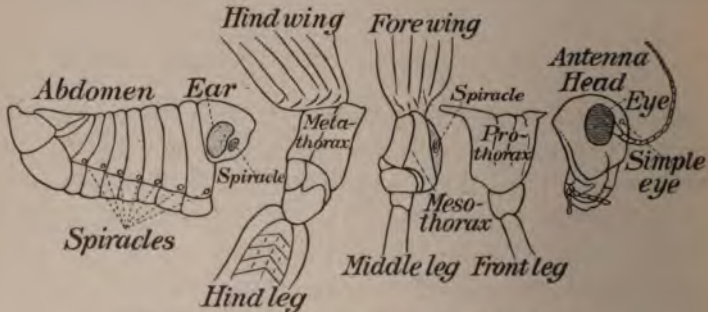

FIG. 94.—Diagram of parts of locust's body.

is made up of a number of rings, or segments. This segmented structure gives flexibility to the body and permits

a limited degree of movement. By closer study it will be found that there are three distinct regions in the body of a locust; namely, head, thorax, and abdomen (Fig. 94). It is well to note, just here, that the bodies of all insects are segmented and divided into three regions as the body of the locust is.

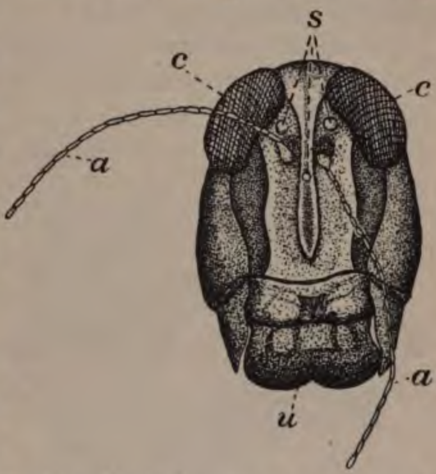

FIG. 95. — Head of locust: *a, a*, antennæ; *c, c*, compound eyes; *s*, simple eyes; *u*, upper lip.

The head and its appendages. — The head of the locust bears several prominent appendages; namely, the antennæ, or feelers, the eyes, and the mouth parts (Fig. 95). The antennæ are slender, threadlike organs attached to the front of the head near the top. Each one is made up of a number of short segments.

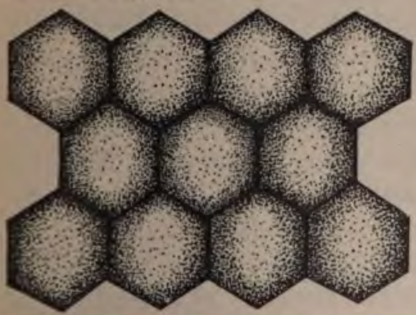
FIG. 96. — Portion of locust's compound eye.

On each side of the head, just back of the antennæ, is a large, conspicuous compound eye. Each one is composed of a number of regular six-sided divisions which give it a honeycomb appearance (Fig. 96). In addition

to the compound eyes there are three simple eyes, one in the middle of the forehead and one at the upper inside corner of each compound eye.

The mouth parts are fitted for biting and are constructed as follows: on the lower part of the face is a notched flap that can be lifted up with a pin (Fig. 95). This is the upper lip; just beneath this are two hard, black bodies with toothed edges, the mandibles (Fig. 97). Below the mandibles is the second pair of jaws, the maxillæ. These are more complicated than the mandibles and each one bears a slender prolongation like an antenna, called a palpus. Finally, below the maxillæ is the lower lip (Fig. 98), which is notched and bears two slender palpi.

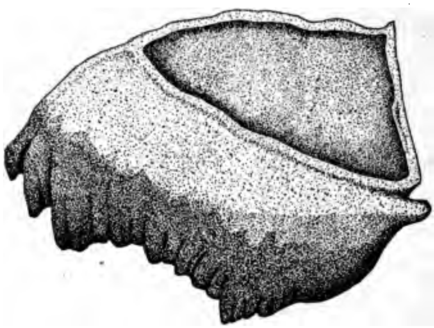

FIG. 97. — One mandible of a locust or grasshopper.

The thorax and its appendages. — The thorax of the locust is composed of three divisions: the *prothorax*, the division next the head; the *mesothorax*, the middle division; and the *metathorax*, the last division (Fig. 94). We can distinguish these divisions by the appendages they bear. For example, there are three pairs of legs on the thorax, of which the first pair is borne by the prothorax, the second pair by the mesothorax, and the third pair by the metathorax. The legs are made up of segments with joints, hence are fitted for movement. The hind pair is very long, large, and muscular. Moreover, the thorax bears two pairs of

wings that extend backward over the abdomen when the insect is in repose. The wings of the first pair are attached to the mesothorax and are long, narrow, and parchment-like, for they serve as a protective covering for the hind pair. The hind wings, which are much larger and thinner than the front ones, are black with a broad yellow edge. They are attached to the metathorax and when the locust is at rest, each hind wing is folded like a fan beneath the corresponding one of the front pair.

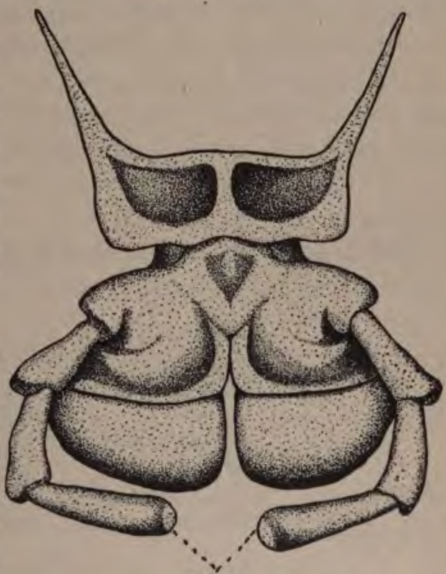

Fig. 98.—Lower lip of a locust: *Pa*, palpi.

The abdomen and its appendages.—The abdomen of the locust is the largest of the three divisions of the body. It is composed of a number of plain, ringlike segments, joined to each other by thin, flexible skin, an arrangement that permits a certain amount of movement of each segment. The abdomen bears few appendages, and these are inconspicuous and at the posterior end. In the female locust the abdomen ends in four curved, pointed pieces which, together, form the ovipositor. It is used for making holes in the ground in which to deposit eggs. There are also two small, curved appendages, the *cerci*.

Locomotion of the locust. — It has three ways by which it can move from place to place. First, it has the two pairs of strong wings suitable for rapid and extended flight. Second, it has six well-developed legs for crawling, although the first four are used mainly in this method of locomotion for the hind ones seem unwieldy and ill adapted to this slow kind of progress. Lastly, it uses the large and muscular hind legs for jumping. In comparison with its size, the locust possesses extraordinary leaping power. Moreover, each of the six legs ends with two hooked claws which enable the locust to retain its hold upon objects while crawling.

The digestive system and food of the locust. — The gullet leads upward (Fig. 99) from the mouth, then turns pos-

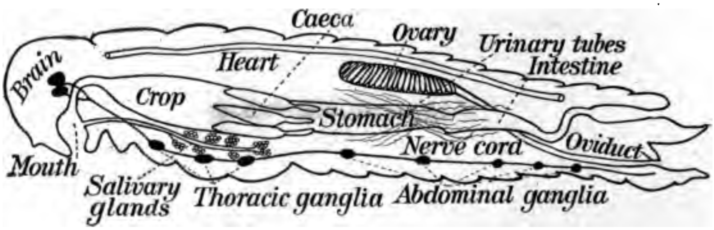

Fig. 99. — Internal structure of a grasshopper.

teriorly and quickly widens into the crop. The salivary glands lie beneath the crop and connect with the mouth through a long, slender tube. The stomach succeeds the crop and lies in the abdomen. Six pairs of long, tapering pouches, the *gastri cæca* (Fig. 99), surround the anterior end of the stomach. They secrete a digestive juice and discharge it into the latter organ. A circle of several slender tubes, the *urinary tubes*, arise from the anterior end of the intestine. They indicate where the stomach ends and the

intestine begins. The intestine makes one bend and then dilates to form the rectum.

A locust eats many different kinds of plants, chiefly grasses and forage and grain plants. They are voracious insects and often eat every growing thing in their path.

How the locust breathes. — The air enters an insect's body through holes along the sides of the abdomen and thorax, and passes into a system of tubes known as *tracheæ*. This is well illustrated by the locust. Figure 94 shows the right side of the abdomen of a locust with the holes called

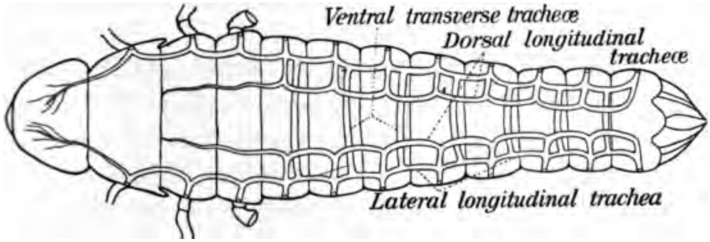

Fig. 100. — Tracheal system of a grasshopper.

spiracles, one on each side of the first eight segments. Note the two spiracles on the thorax, also. From each spiracle a short trunk runs inward and connects directly with two large tubes that run lengthwise, one on each side of the body cavity (Fig. 100). Closely connected with these are two long tubes running along the dorsal side of the body cavity. There are also two shorter and smaller air tubes along the ventral side of a part of the abdomen. All of these main tracheæ send off smaller tubes that divide and subdivide into smaller and smaller branches which reach every part of the body, even entering the legs and wings to some extent.

"The tubes are filled and emptied by a rhythmic, alter-

nately contracting and expanding movement of the abdomen called the respiratory movement."

The circulatory system of the locust. — The blood vessels and the circulation of the blood in insects are well shown by a study of the locust. The circulation of insects is not well developed. The only blood vessel in the locust, for example, is a long, slender, tubular organ that runs along the dorsal side of the body cavity in the abdomen and thorax and extends into the head. This is known as the *dorsal vessel,* and that part of it lying in the abdomen is the *heart,* while the anterior part, in the thorax, is the *aorta.* The heart is closed at its posterior end, but has openings along each side through which the blood enters and, by contractions of the heart, is forced forward through the aorta into the head. Valves within the heart prevent the blood from flowing backward through it. The blood is usually a colorless liquid and fills all the spaces of the body cavity, literally bathing the tissues and organs of the insect. It does not carry oxygen because this is done by the air tubes. Its function is to carry the products of digestion from the alimentary canal.

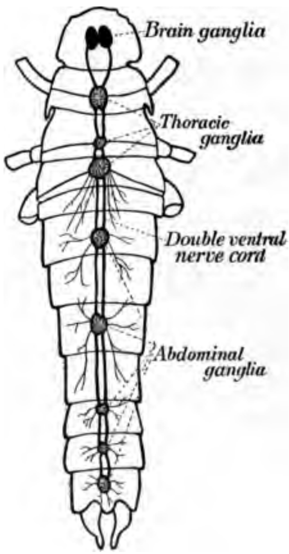

Fig. 101. — Nervous system of a grasshopper.

The nervous system. — The brain consists of three large ganglia closely connected and lying above the gullet in the head. From the brain the nerve cord passes posteriorly, one strand going down the left side of the gullet and the other

strand down the right side, after which they are united again throughout the length of the body (Fig. 101). There are three ganglia in the thorax and five in the abdomen (Fig. 101). With its eyes the locust has a fairly keen sense of sight for short distances, at least. On each side of the first segment of the abdomen is a circular tympanic membrane, the ear (Fig. 94). The sense of touch is located chiefly in the antennæ.

Excretory system of the locust. — The excretory organs of the locust consist of a number of very slender tubes, the urinary tubes (Fig. 99), attached to the anterior end of the intestine. They lie in a tangled mass about the stomach and intestine, and extract from the blood much the same products that the kidneys of the vertebrates do and pour them into the intestine to be carried out from the body.

Reproduction of the locust. — The ovaries of the female lie above the alimentary canal in the abdomen (Fig. 99), and, when full of mature eggs, occupy a large part of the abdominal space. In the fall, when ready to deposit her eggs, the female thrusts the four pointed pieces composing the ovipositor into the ground, then separates them, thus pressing back the dirt. By repeating this process, she finally forms a hole of the required depth to hold her eggs. The eggs are then deposited in a capsule or pod where they remain until the following spring, when they hatch and the young locusts appear. The young, the moment they hatch from the egg, may be recognized as locusts. They are known as *nymphs*. They eat voraciously and grow very fast, becoming mature in about two months. During this growth they molt, or shed their skins, several times. After the first molt the wings appear as small, backward-projecting pads. With each successive molt the wing pads

become larger and larger until after the last molt they appear fully developed (Fig. 102). Such a development — in which the egg hatches into a form resembling the adult — is known as a direct development, and insects having a

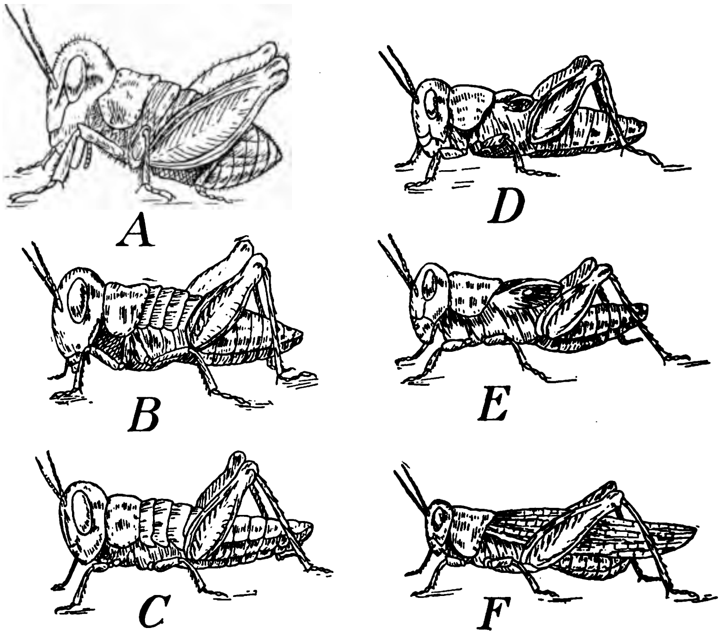

FIG. 102. — Nymphs of a locust: *A*, first stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, fifth stage; *F*, final stage. After Emerton.

direct development are said to have an *incomplete metamorphosis*.

Economic importance of the locusts. — Since locusts persistently feed upon grasses, grains, and forage crops, they are of considerable economic importance, although the Carolina locust does not cause so much injury as some other species. The Rocky Mountain locust, that in past years

has swept over the western states in vast swarms, has proven itself one of the worst insect scourges that this country has ever seen. At such times it literally ate all the vegetation in its path and almost produced a famine in the territory it touched. Fifty millions of dollars' worth of farm products were eaten by these locusts in the seasons of 1874–1876 alone. Asia and South America have their swarms of migratory locusts. A swarm of locusts covering an area of two thousand square miles passed over the Red Sea in November of 1889, a truly modern plague of locusts.

How the locust is protected. — The color of the locust's wings blends so nicely with the dusty highways and the bare roadsides that many of its enemies must fail to find it. Besides, its strong wings enable it to take swift and immediate flight if in danger. Finally, its strong hind legs enable it to leap quickly out of the way of many of its enemies.

Another Example of the Insecta — the White Cabbage Butterfly (Fig. 103)

How the butterfly resembles the locust. — The butterfly has the body segmented and divided into three main regions: head, thorax, and abdomen, similar to the locust. It also has six segmented legs and two pairs of wings borne by the thorax, as in the locust. Its digestive, excretory, and circulatory systems are practically the same as those of the locust.

How the butterfly differs from the locust. — The butterfly differs from the locust in the structure of its wings; the structure of its mouth parts; the kind of food eaten and the manner of eating it; in its manner of locomotion; in

the structure of the hind pair of legs, at least; in its life history; in the form of its antennæ; and in the absence of simple eyes.

Wings of the butterfly. — If a butterfly is caught in the hand, a fine, dustlike substance is always rubbed from the wings by contact with the fingers. If this substance be examined under a microscope, it will be found to consist of tiny, flat, somewhat fan-shaped bodies called *scales*. The wings of butterflies are always clothed with scales that overlap like shingles on a roof (Fig. 104). They undoubtedly aid in strengthening the wing. When the scales are all removed from the wing, it appears as a thin transparent membrane with veins running lengthwise and with few cross veins (Fig. 105). The wings of the butterfly are never folded like those of the locust, but are held vertically when the insect is at rest.

FIG. 103. — White cabbage butterfly, larva, and pupa.

The legs of the butterfly. — Although this insect has six legs they are weak and are little used for locomotion but rather for the purpose of clinging to objects upon which the insect may alight. Again, although the hind legs are larger than those of the other pairs they are not large and muscular like the hind legs of a locust and are not used for jumping.

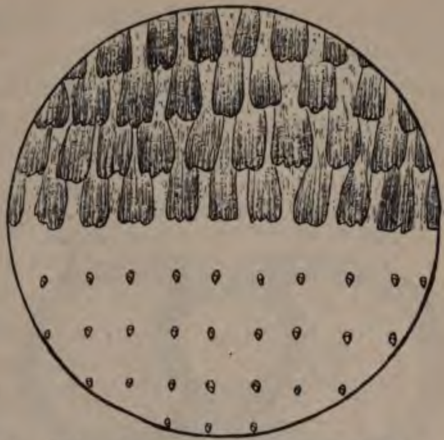

Fig. 104. — Piece of the wing of a butterfly enlarged to show the arrangement of the scales. The scales have been removed from the lower half to show the places of attachment.

Mouth parts of the butterfly. — A butterfly has its mouth parts constructed for sucking. The mandibles are lacking entirely and both lips are small and inconspicuous. The maxillæ, however, are present, and each one is greatly elongated and grooved on its inner surface. Moreover, they are joined together by their inner surfaces in such a way that the two grooves meet and form a tube (Fig. 106) through which liquid food is drawn. The proboscis formed by the union of

Fig. 105. — Wings of a butterfly after the scales have been removed.

the two maxillæ is carried coiled beneath the head (Fig. 107).

Butterflies live upon the nectar extracted from flowers with the proboscis.

Locomotion of the butterfly. — This insect has two methods of locomotion, namely, flying and walking. The legs are weak and not very efficient organs for walking. At best, the walk of a butterfly is jerky and feeble. They depend mainly upon their wings for locomotion, and these organs are every efficient. The flight is usually irregular, but is swift and capable of long duration. Some butterflies migrate regularly according to the seasons.

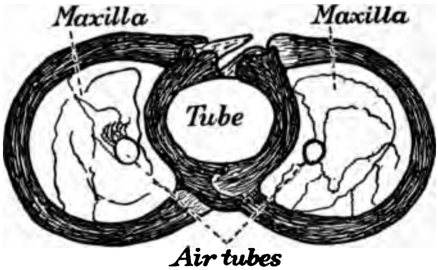

FIG. 106. — Cross section of the proboscis of a butterfly. After Comstock.

The form of the butterfly's antennæ. — The antennæ are composed of short, thick segments and are straight. Moreover, they are always enlarged at the ends with a sort of knob.

Life history of the butterfly. —In its life history the butterfly differs most markedly from the locust. The former has what is known as an indirect development or a "complete metamorphosis." The female lays her eggs on the cabbage leaves and from

FIG. 107. — Head of a moth, showing mouth parts modified into a long proboscis or sucking tube.

these there hatch tiny green caterpillars. They eat ravenously, and grow very fast, shedding their hardened skins from time to time so that their bodies may stretch and become larger. In a few weeks the caterpillars become mature. Each one then passes through a great change and becomes transformed into a quiescent body known as a *pupa*. The pupa is encased in a hard, shiny covering and the whole is called a *chrysalis*. The chrysalids of some butterflies are beautifully spangled with gold and silver spots, but the chrysalis of the cabbage butterfly is modest in coloring. It is suspended from the cabbage leaf by the tail and by a loose band about the middle (Fig. 108). The pupa lies quietly, eats nothing, and at the end of about ten or twelve days splits open down the back and the adult butterfly crawls out, dries its wings in the sun, and in a little while flies away in quest of something to eat.

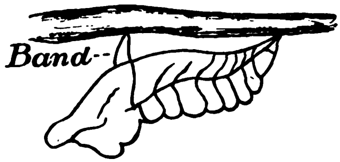

Fig. 108. — Pupa of butterfly.

XVI. OTHER MEMBERS OF THE CLASS — INSECTA

Arthropoda (*continued*)

Locusts, crickets, katydids, and cockroaches. — These are all closely related insects and belong in one group. There are many species of locusts and they are widely distributed over the earth. The little red-legged locust is very common in the northern states, while the great American locust is conspicuous in the southern states (Fig. 109).

Fig. 109. — American locust.

There are two families of locusts: the short-horned, those having short antennæ, and the long-horned, those with long, slender antennæ. The former are represented by the Carolina and American locusts, while the latter are best represented by the slender, green locusts found among the grass in meadows. Locusts produce their sounds in two different ways. Some species rub the hind legs, while at rest, across a ridged vein on the outer surface of the first pair of wings. Other species, while in flight, rub or strike together the upper surface of the front edge of the hind wings and the under surface of the fore wings. This produces a loud, sharp, clacking sound. Some species lay their eggs in the fall and some in the spring. The eggs

are laid sometimes in the ground and at other times in logs, stumps, rails, etc.

The crickets possess long, slender antennæ which are unlike the shorter and stouter ones of the common locust. The large veins at the bases of the wing covers of the males are ridged somewhat like a file (Fig. 110). When "chirping," or "shrilling," the cricket elevates the wing covers at an angle of about forty-five degrees and rubs one against the other where the ridged veins are, thus throwing them into vibration and producing the noise. Only the male sings.

FIG. 110.—Large vein at the base of a cricket's wing. Enlarged to show the filelike ridges.

The katydids usually possess large green wing covers which resemble closely the leaves of trees in which these insects live. Katydids, like the crickets, possess long, delicate antennæ, and the males make their peculiar noise in the same manner as the crickets (Fig. 111).

FIG. 111.—Katydid on an oak leaf.

The katydids and crickets have ears, or at least hearing organs, on their fore legs.

In kitchens and bathrooms, around water pipes and sinks, are found those annoying insects known as cockroaches. They are often troublesome because they get into places where it is not pleasant to us to have them and at the same

FIG. 112. — Cockroach: *E*, egg case.

time eat nearly everything they can find. The eggs of a cockroach are laid all at a time in a sort of pod or capsule (Fig. 112).

The mantes are common in the South and are known as "praying mantes," or "mule killers." The term "praying" comes from the apparently devout attitude assumed by the insect. The eggs are laid in clusters on the branches of trees or in other convenient places. The clusters are large,

usually whitish in color, and have the appearance of being braided on top (Fig. 113). The mantes are predaceous upon certain injurious insects and for this reason they should be protected.

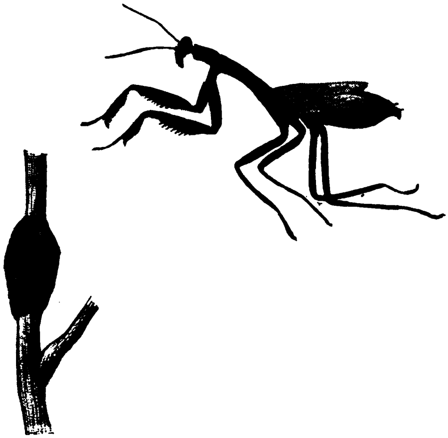
FIG. 113. — Praying mantis, and cluster of eggs.

Dragon flies. — These are the large graceful insects that are so abundant around ponds and along the shores of lakes and streams. They are known as "devil's darning needles," "snake doctors," etc. (Fig. 114). They have long, slender bodies and two pairs of strong, transparent wings of about equal size and with many longitudinal and cross veins. When flying, they dart swiftly back and forth over the water; but when they alight, they sit motionless — most species with outspread wings — on the dry, projecting stems of plants. They have powerful jaws and great round eyes, and live upon other insects caught while on the wing. Most of their prey they capture and hold with their legs and eat while flying.

The eggs of dragon flies are either attached to the stems of water plants below the surface of the water or are laid loosely in the water, or, in some cases, are inserted within the tissues of the plant stems. They hatch into ferocious nymphs with strong jaws and enormous appetites. The

nymphs live upon other aquatic insects, as the larvæ of mosquitoes, for example, which they devour greedily when they are to be found.

Squash bug, harlequin cabbage bug, plant lice, etc. — There is a very large group of insects, including the ones named and many others, as the water boatmen, backswimmers, stink bugs, giant water bugs, etc., that are known as "bugs." Most people call any insect a bug; but entomologists restrict the term to insects like those mentioned in this paragraph. Unlike the locusts, the bugs have sucking mouth parts. The mandibles and maxillæ have grown out into long, slender, bristlelike organs. These four bristles are inclosed in a segmented sheath formed by the lower lip (Fig. 115). The bristles and sheath together form a "bill," or "beak," as it is called. This beak is plainly seen on the ventral side of the thorax, between the bases of the legs, in a squash bug, harlequin cabbage bug, or dog-day harvest fly.

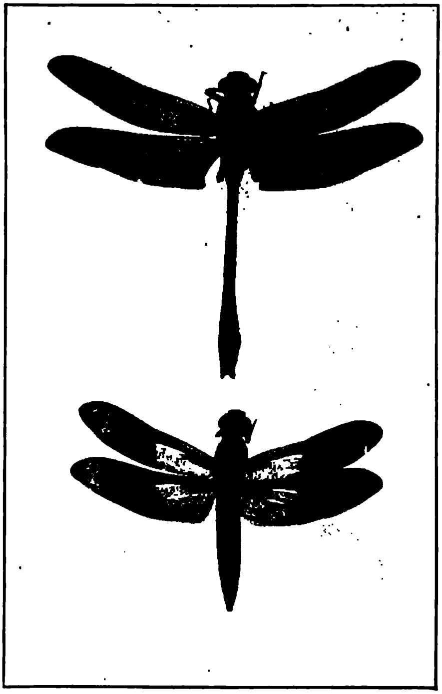

FIG. 114. — Dragon flies.

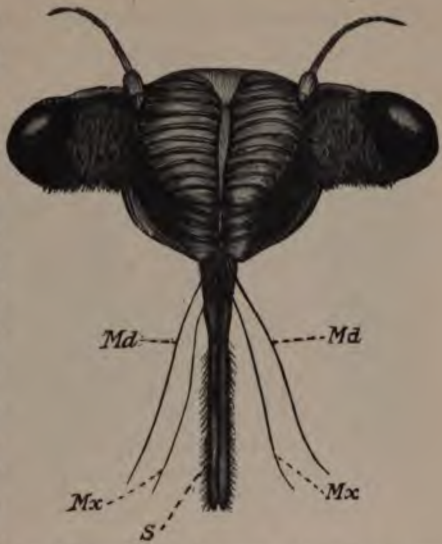

FIG. 115.—Head of dog-day harvest fly, enlarged to show mouth parts: *Md*, mandibles; *Mx*, maxillæ; *S*, sheath, formed by the lower lip, in which the four bristles are carried.

With care the bristle-like mandibles and maxillæ may be separated from the sheath. Many of the bugs are injurious to farm crops. They insert their beaks into the tissues of plants and suck out the juices, thereby weakening, if not killing the plants. The squash bug (Fig. 116) lays its eggs, usually, on the under sides of leaves. The young bug passes through five stages, gradually getting wings and becoming larger, before it reaches the adult condition.

The harlequin bug, or "calico back," or "terrapin bug," as it is variously called, is very injurious to cabbages, turnips, radishes, etc. Its life history is similar to that of the squash bug (Fig. 117). There are seven or eight generations of this bug during a season in the South.

FIG. 116.—Eggs, nymph, and adult of squash bug.

The cicadas. — The seventeen-year cicada (or locust) lays its eggs in slits made in young twigs. The young hatch

FIG. 117. — Life history of a harlequin cabbage bug: *e*, eggs; *n*, nymph; *a*, adult.

in about six weeks and quickly enter the ground, where they live on the soil humus and sap of the tree roots for nearly seventeen years. In the early summer of the

FIG. 118. — Seventeen-year cicada.

seventeenth year, the nymphs come out of the ground, crawl up the trunk of the tree, where the skin bursts open on the back, and the adults (Fig. 118) pull themselves out,

leaving the empty nymph skins clinging to the tree. In the South these cicadas live thirteen years in the ground. The dog-day harvest fly (Fig. 119) is the insect responsible for much of the high, sharp trilling that comes to us in the

FIG. 119. — Dog-day harvest fly.

hot summer days from the trees where the singer lies hidden. It takes this cicada only two years to develop, and, since there are two broods, the adults appear every year.

That large group of insects known as the scale insects belongs to the same order as the bugs and cicadas. These are small, louselike insects which, in many cases but not all, secrete a hard, waxy covering, or scale over the body. They are often exceedingly injurious and, hence, of great economic importance. The San José scale insect is probably the most important species in the United States (Fig. 120). It is a great pest to apple, pear, and peach trees.

Butterflies and moths. — These are familiar insects, because they are abundant everywhere and many of them are of large size. The butterflies are perhaps better known than the moths, because they are more brilliantly colored,

as a rule, and because they fly in the daytime, and moths, for the most part, fly at night. Moreover, the body of a butterfly is slender, while the body of a moth is stouter and more robust. The wings of a butterfly, when in repose, are held vertically, while those of a moth are folded, roof-like, over the abdomen. The pupa of a butterfly is naked and is known as a chrysalis, but the pupa of a moth is usually inclosed in a cocoon of silk, which, in turn, may be wrapped with leaves. The wings of both moths and butterflies are clothed with scales and they all have an indirect development, while the mouth parts of almost all are formed for sucking.

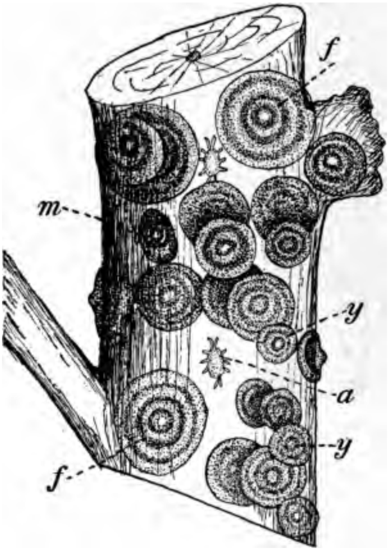

FIG. 120.—San José scale insect: *m*, male scale; *f*, female scale; *y*, young scale; *a*, young insect. Enlarged.

The swallowtails are our largest butterflies, and are easily recognized by the prolonged, tail-like appendages of the hind wings. The black ground color of the wings (Fig. 121) is usually conspicuously banded and marked with yellow, and metallic blue or green. The larvæ, or caterpillars, of these butterflies are common on caraway and parsley, and on apple, cherry, plum, tulip trees, etc. The caterpillars are peculiar and interesting, because each one has two fleshy "horns" that may be pushed out through a slitlike opening on the top side of the front of

the thorax. The horns are thought to be for the purpose of defense; for in some species, at least, they exhale, when pushed out, a very disagreeable odor. There are several species of swallowtails, among which are the black

FIG. 121.—Swallowtail butterfly.

swallowtail, the tiger swallowtail, and the zebra swallowtail.

The monarch is a very common butterfly and is abundant over the middle and eastern United States. It has light, tawny brown wings with black veins and two rows of white spots around the edges. The caterpillars, which live upon various species of milkweed, are yellowish in color and banded with black. The chrysalids are bright green, dotted with gold.

Moths. — Even a beginner will hardly mistake a moth for a butterfly. The caterpillars of moths are, as a whole, very much more abundant and more injurious than those of butterflies. There are also many more species of moths than butterflies. The larvæ of some moths are among our worst insect pests.

FIG. 122. — Tomato worm and moth.

The large green "worms" found on tomato plants are the larvæ of a magnificent hawk moth (Fig. 122). The moth has long, narrow, graceful wings that are ash-gray in color, and marked with black or very dark gray. The abdomen has five yellow spots along each side.

A small moth, known as the codling moth, lays its tiny white eggs on the surfaces of young green apples (Fig. 123). The eggs hatch and the young larvæ bore into the apple, in most cases entering at the blossom ends, and causing wormy apples.

FIG. 123.—Codling moth, with its egg on the apple at the left and its larva in the apple at the right.

Sometimes a field of cotton is attacked by caterpillars in such numbers that they are known in the South as the "army worms." These "worms" are the larvæ of the cotton moth (Fig. 124). This moth lays its eggs upon the

cotton plant, where they hatch into caterpillars that soon destroy the leaves if left unmolested.

FIG. 124.—Stalk of cotton, showing the egg (e), larva (a), pupa (b), and adult of the cotton worm moth.

One of our larger moths, the polyphemus moth, is shown in Figure 125. The larvæ of this moth feed upon the leaves

of elm, apple, pecan, etc. The peach tree borer is the larva of a clear-winged moth.

FIG. 125. — Polyphemus moth.

The larvæ, or caterpillars, of moths vary greatly in size and appearance. Some of them are so small as to be able to live all their lives between the upper and under surfaces of leaves. Others live in grains of wheat and corn. Some, on the other hand, are five or six inches long and thicker than one's thumb.

FIG. 126. — Egg rafts of common mosquito (*Culex*). Enlarged.

Flies. — This is a large group of insects containing many kinds of flies, gnats, and mosquitoes. They are all alike in one

respect, — they never possess more than one pair of wings. Some possess none. In the place of the second pair borne by locusts, bugs, and butterflies, a pair of short, knobbed hairs, called balancers, is found. Though insignificant in appearance, the mosquito has become one of the most important insects of this group. It has been demonstrated beyond a doubt that a certain kind of mosquito, called *Anopheles* may bear within its body, if it has previously bitten a person having malaria, the germ that causes malaria. Moreover, whenever this particular kind of mosquito bites a person, it injects some of those germs into the blood of that individual, thereby inducing malaria. Very good proof has also been adduced to the effect that a certain species of mosquito carries yellow fever from one person to another. Thus it has happened in recent years that the mosquitoes have become very notorious insects. The

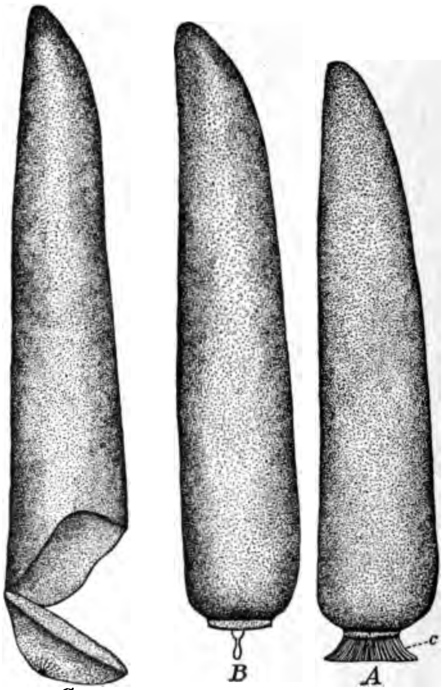

FIG. 127. — Eggs of mosquito, enlarged: *A*, fresh egg with collar; *B*, egg a little older, without collar; *C*, shell from which the wiggle-tail has escaped.

female of a common species of mosquito lays its eggs — two or three hundred — in small, dark, boat-shaped masses (Figs. 126 and 127) on the surface of the water. In about two days these hatch into minute larvæ called "wiggletails" or "wigglers" (Fig. 128). The "wiggletails" live in the water, but are obliged to come to the surface for air. Here they hang head downward (Culex) with a tube, called the breathing tube, on the end of the abdomen, projecting just above the surface. Through this tube, they take in the air. They live in this manner for about a week and then change to pupæ (Fig. 129). The pupæ are also active, and they have the anterior end of their bodies greatly enlarged. They eat nothing, and in a few days their skins split open on the back, and the adult mosquitoes (Fig. 130) come forth.

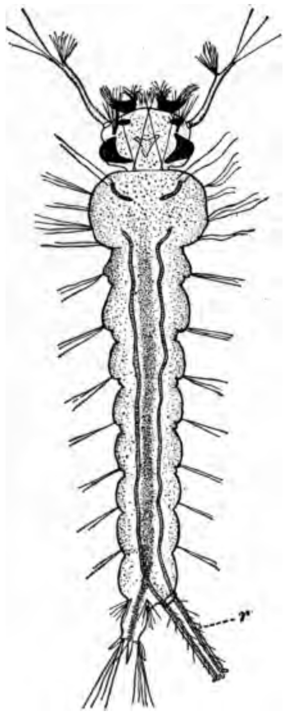

FIG. 128. — Wiggler of common mosquito, enlarged: *r*, breathing tube.

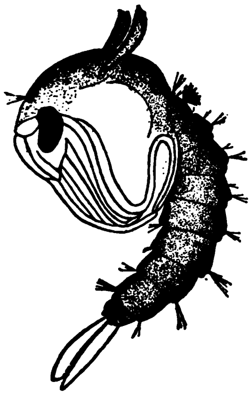

FIG. 129. — Pupa of common mosquito, much enlarged.

In general, the mouth parts of flies are formed for sucking like those of the mosquitoes. Familiar members

of this group are the horsefly (Fig. 131), the blowfly, house fly, gnats, midges, etc.

Flies pass through a complete metamorphosis in their life history. The egg produces a larva, usually whitish in color, without feet. It is called a maggot. When it changes to a pupa, it seldom makes a cocoon; but many transform within the last larval skin which serves as a cocoon.

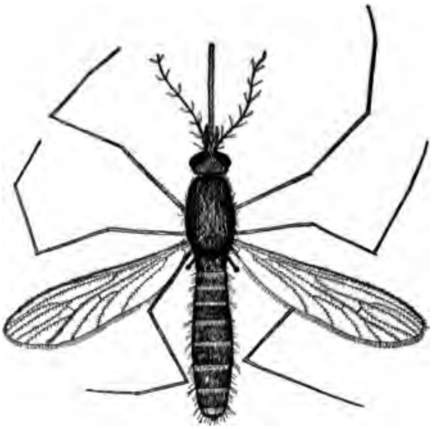

FIG. 130.—Common mosquito, enlarged.

Beetles.—This is the largest group of insects. The beetles differ from other insects in having a pair of hard wing covers (Fig. 132). These covers are usually much harder and thicker than those of the grasshopper and cricket. Beetles may almost surely be told by this character. Their mouth parts are formed for biting and their development is direct.

FIG. 131.—Horsefly.

The Colorado potato beetle is a familiar example (Fig. 133). It is a yellow-lined beetle and lays its reddish eggs close together in a bunch, usually on the under sides of the leaves of potatoes. The soft red larvæ soon appear and immediately begin to eat the leaves. The larvæ keep on eating and growing for two or three weeks and then go into the ground to pupate.

The May beetles, or June bugs, are abundant in spring, flying in through the windows and bumping about the room. Their eggs are laid at the roots of grass, and the white grubs live in the soil, eating off the grass roots. The larva lives in the ground two or three years and changes to a pupa in an earthen cell from which the adult comes later. In the South the fig eater is most often called the June bug.

FIG. 132.—Four common beetles.

The plum curculio is a small rough beetle with a long snout, that lays its eggs beneath the skin of plums, peaches, prunes, etc. The larva, or "grub," burrows into the fruit and lives there for about one month, causing "wormy" plums and peaches. It finally enters the ground to pupate, and after about five or six weeks the adult beetle comes forth.

The Mexican cotton boll weevil is a small snout beetle that is exceedingly injurious to cotton (Fig. 134). It came into the United States from Mexico and is gradually spreading over the cotton belt. The young larva eats the tender inside portions of the squares or bolls and so destroys them.

Other examples of beetles are the adults of "wireworms," "betsey bugs," "blister beetles," "carrion beetles," etc.

Many beetles are injurious to trees, fruits, grains, and vegetables.

Bees, wasps, and ants. — These insects have clear, membranous wings and are, perhaps, the most instinctively

FIG. 133. — Potato stalk, showing life history of the Colorado potato beetle.

intelligent of all insects. They have an indirect development. The larvæ of the bees, wasps, and ants are white, footless grubs, and the pupæ of ants are often inclosed in cocoons. The mouth parts of these insects are formed for

sucking and biting, and, in this respect, bees and wasps are perhaps superior to other insects.

Every one is perfectly familiar with ants; but every one, perhaps, is not familiar with the fact that in a nest, or colony, of ants there are always three classes, — males, females, and workers. The workers, as their appellation implies, do all the work of the colony, — obtain food, build

FIG. 134. — Mexican cotton boll weevil: much enlarged, above; natural size, below.

the nest, care for the young and the queen, and fight the battles. The queen lays the eggs, but is in no sense the ruler.

There are certain kinds of ants that make slaves of other ants. The workers sally forth in a body to war on other ants, and, if successful, they bring back larvæ and pupæ and rear them as slaves in their own colony. One species of slavemaker ants has become so dependent on its slaves that the individuals cannot care for themselves and, if left alone, would die.

On the other hand, some species of ants care very tenderly for certain kinds of insects known as plant lice. The plant lice give forth a sweet substance, honey dew, of which the ants are fond. The ants of one species actually build coverings over the lice to protect them, while those of another

Fig. 135. — Nest of Polistes: some of the open cells contain eggs, and some larvæ; the closed cells contain pupæ.

species take the eggs of the plant lice to their nests and care for them during the winter.

Wasps, hornets, and yellow jackets are mostly social insects and live in colonies in nests built of papery material. They make these nests of bits of wood obtained from fences, stumps, etc. These bits are chewed fine and converted into a paste by their jaws, and then allowed to dry.

One kind of wasp builds a nest composed of a horizontal comb of many cells, side by side, without any covering (Fig. 135), and suspended from some object by a small stem, or peduncle. These wasps are black and ringed with yellow or are brownish (Fig. 136). The familiar yellow jackets (Fig. 137) and hornets build nests composed of several layers of comb surrounded by a gray papery material (Fig. 138). The nests of the yellow jackets are usually built in the ground. The colonies of social wasps consist of males, females, and workers. Every colony is broken up in the autumn, only the females surviving.

FIG. 136.—A wasp (*Polistes*) that builds an uncovered layer of cells for a nest.

The familiar nests of the mud-dauber wasps (Fig. 139) consist of several layers of long cells made of mud, lying side by side. They are built in the attics of houses or in barns or other outbuildings. The adults may be seen about puddles of water, gathering mud to build their nests. An egg is laid in each cell which is then filled with living but paralyzed spiders to furnish food for the young wasps.

FIG. 137.—Yellow jacket wasp.

Not all wasps are social. Some live alone, hence are called solitary. They build their nests in a variety of situations, usually in holes which they excavate in soft wood or which they find already made.

The social bees — honeybees and bumblebees — are of considerable economic value to man. The honeybee furnishes us with two most valuable products, honey and wax, while the bumblebee cross-fertilizes our fields of clover. Yet it is not of the social bees that we shall speak, but rather of the solitary ones with which we are not so familiar. Perhaps the small carpenter bee, the large carpenter bee, and the leaf-cutter bees are the most common of the solitary bees. The female of the small carpenter bee is about a quarter of an inch long. She selects a twig, most often of the sumach, that has a soft pith and excavates in it a long tunnel. At the bottom she puts in a supply of pollen, lays an egg, and then builds a partition above it, lays another egg on pollen, builds another partition, and so on until only room enough is left for her to rest at the mouth of the tunnel, to watch and wait until the young bees appear.

Fig. 138. — Nest of Vespa.

Fig. 139. — Nest of mud-dauber: the uncapped cells show that the young wasps have become mature and flown away.

There is a large carpenter bee that bores into solid wood and builds a nest there much like that of the smaller one.

The leaves of rose bushes are often found with oblong and circular notches neatly cut along the edges. This is the work of a small leaf-cutter bee (Fig. 140). This bee first builds a tunnel in partly decayed wood, then cuts oblong pieces from rose leaves and builds a short tube at the bottom of the tunnel. The bee then fills the tube partly full of a pasty mass of nectar and pollen and lays an egg on top. After the egg is laid the bee cuts circular pieces from the rose leaves which are a little larger than the diameter of the tube, and pushes them into the mouth of the tube, completely stopping it. In this way the tube is filled with short cylindrical cells, each containing an egg (Fig. 141).

FIG. 140.—Leaf-cutter bee and rose leaf cut by it.

Adaptations of insects to their environments.—Perhaps among no other group of animals can there be found so many and so varied adaptations to meet the surrounding conditions as among the insects.

Dragon flies live mainly on mosquitoes, gnats, and other

small insects caught in the air while on the wing. The long, strong wings of the dragon flies and the large eyes with which they can see on all sides are distinct adaptations for catching these insects. The nymphs of the dragon flies live in the water and are furnished with gills to adapt them to such a life.

FIG. 141.—Nest of leaf-cutter bee.

The bee's hind legs are furnished with thick rows of long bristles which serve as receptacles in which the bee carries the pollen to the hive. The lower lips of honeybees and of bumblebees are long, to enable them to suck nectar from flowers.

The maxillæ of many butterflies and moths have been developed into long probosces to enable them to procure nectar from deep flowers. This is well shown in those large hawk moths that frequent honeysuckles at dusk.

Many grasshoppers are colored like the soil on which they live. This is well shown in the case of those grasshoppers that are so frequently found along dusty highways. It is difficult to find one of these insects after it alights, so closely does it resemble the soil.

The bodies of fleas are greatly compressed and these insects are thereby enabled "to glide through the narrow spaces between the hairs of their hosts."

The so-called flat bugs have thin flat bodies, which enable them to live between the bark and wood of decaying stumps and logs.

Katydids have green wings with veining to resemble leaves. The walking sticks greatly resemble sticks.

A most interesting line of field work may be instituted and carried on throughout nearly the whole year, especially in the southern states, on the habits of insects and their adaptations to their environments.

Economic importance of insects.—The damage that insects do to agricultural and horticultural interests is apt to overshadow the benefits these smal animals confer upon mankind. We should not forget that bees are specially useful in cross-fertilizing many of our fruits and certain of our forage plants, notably red clover. The usefulness of the bumblebee, in this respect, was demonstrated when it was found that red clover in Australia did not produce seed until this bee had been imported to cross-fertilize the flowers of the clover plant.

A most notable demonstration of the value of insects in the cross fertilization of fruits has been made by the Bureau of Entomology of the United States Department of Agriculture in connection with fig growing in California. To produce the best quality of fruit the flowers of the cultivated fig must be cross-fertilized with the pollen from the wild fig. The structure of the fig flower is such that this can be done only by a small fly, the Blastophaga, heretofore not found in the United States. After many trials and with most praiseworthy persistence the Bureau of Entomology succeeded in importing this fly from the fig-growing districts of Europe and in establishing it in California with the result that that state is now producing, annually, many tons of figs pronounced by experts to be superior, in some respects, to the imported Smyrna figs.

Scale insects give us cochineal and carmine and some of

them produce the shellac used in finishing furniture, etc. The products of the honeybee amount to hundreds of thousands of dollars each year.

After all, it is in the rôle of destroyers of fruits, garden crops, forest trees, and cereals that insects assume their greatest economic importance. It is estimated that the chinch bug destroys forty million dollars' worth of wheat every year. The Mexican cotton boll weevil destroyed between ten and fifteen millions of dollars' worth of cotton in Texas in 1903. The weevils and the angumois grain moth that live in stored grains destroy many million bushels of corn, wheat, peas, and beans every year. Professor Sanderson says that three hundred million dollars is a conservative estimate of the amount of damage done annually by the Colorado potato beetle, tobacco worm, cotton worm, boll worm, plum curculio, San Jose scale, cabbage worms, chinch bugs, grain weevils, and other insects.

Chief characteristics of the insects. — Insects have six legs; breathe air directly through a system of tracheal tubes; pass through certain remarkable changes, or metamorphoses, in their life history; possess one pair of antennæ, two compound eyes and, in many cases, one or more simple eyes, and usually wings in the adult state. Recall the chief characteristics of the Arthropoda as a whole.

CLASSIFICATION OF THE ARTHROPODS

Branch XI — Arthropoda.
- *Class* — Crustacea.
  - *Subclass* — Entomostraca.
    - Order — Cirripedia.
      - Types of Order.
        - *Lepas species* — Barnacle.
        - *Balanus porcatus* — Acorn shell.

Order — Ostracoda.
Type of Order.
Cypris species — Water flea.
Order — Copepoda.
Type of Order.
Cyclops species — Water flea.
Subclass — Malacostraca.
Order — Decapoda.
Types of Order.
Homarus americanus — Lobster.
Cambarus species — Crayfish.
Crangon vulgaris — Shrimp.
Penæus setiferus — Southern shrimp or prawn.
Eupagurus longicarpus — Hermit crab.
Cancer irroratus — Crab.
Chionœcetes opilio — Arctic spider crab.
Gelasimus pugnax — Fiddler crab.
Order — Arthrostraca.
Type of Order.
Oniscus species — Sow bug.
Class — Arachnida.
Order — Scorpionida.
Type of Order.
Buthus carolinus — Scorpion.
Order — Araneida.
Types of Order.
Epeira species — Spider.
Mygale species — Trapdoor spider.
Eurypelma hentzii — Tarantula.
Order — Acarina.
Types of Order.
Boophilus annulatus — Southern cattle tick.
Tetranychus telarius — Red spider.
Dermacentor americanus — Dog tick.
Class — Myriapoda.
Order — Chilopoda.

Type of Order.
Scutigera forceps — Centiped.
Order — Diplopoda.
Type of Order.
Julus nemorensis, or *canadensis* — Milliped.
Class — Insecta.
Order — Orthoptera.
Types of Order.
Melanoplus femurrubrum, *Schistocera americana.* — Locust.
Gryllus species — Cricket.
Microcentrum retinervis — Katydid.
Order — Odonata.
Type of Order.
Libellula species — Dragon fly.
Order — Lepidoptera.
Types of Order.
Alabama argillacea — Cotton worm.
Heliothis obsoleta — Boll worm.
Sanninoidea exitiosa — Peach-tree borer.
Carpocapsa pomonella — Codling moth.
Order — Hemiptera.
Types of Order.
Murgantia histrionica. — Harlequin cabbage bug.
Anasa tristis — Squash bug.
Notonecta species — Back swimmer.
Euschistus servus — Stink bug.
Belostoma americana — Giant water bug.
Cicada tibicen — Dog-day harvest fly.
Cicada septendecim — Seventeen-year locust.
Order — Diptera.
Types of Order.
Culex pipiens and *Anopheles maculipennis* — Mosquitoes.

Musca domestica — House fly.
Calliphora vomitoria — Blowfly.
Gastrophilus equi — Horsefly.

Order — Coleoptera.

Types of Order.

Leptinotarsa decem-lineata — Colorado potato beetle.
Lachnosterna species, *Allorhina nitida* — June bugs.
Cicindella species — Doodle bugs.
Drasterius elegans — Wireworm.
Passalus cornutus — Betsey bug.
Anthonomus grandis — Mexican cotton boll weevil.

Order — Hymenoptera.

Types of Order.

Formica exsectoides — Mound-building ant.
Monomorium pharaonis — Red ant.
Formica difficilis — Slavemaker ant.
Vespa species — Yellow jackets.
Polistes species, *Vespa species* — Social wasps.
Eumenes fraternus — Mason wasp.
Apis mellifica — Honeybee.
Ceratina dupla — Small carpenter bee.
Xylocopa virginica — Large carpenter bee.
Megachile species — Leaf-cutter bee.

XVII. BRANCH XII. — CHORDATA (*chŏrd*, cord)

If we recall, thoughtfully, all the animals thus far studied, we shall find that they are conspicuous for the *lack* of one thing. That is, that they have no backbone or anything to take the place of a backbone; hence they are called invertebrates (*in*, without; *vertebra*, joint). All the remaining members of the animal kingdom are conspicuous from the fact that they have a spinal column or some structure that takes the place of it at some period of their life. Those that possess a real backbone, as most fishes, all birds, and mammals, are known as *vertebrates*. Some of the animals with which we are yet to become acquainted have no spinal column, but they do have a structure that takes the place of it. This is a soft, flexible rod, or cord, that tapers to both ends and lies along the back, where the backbone lies in vertebrates. Again, a very few animals —some sea squirts —possess this cord only in their youngest stages, losing it entirely when full grown. Finally, all vertebrates, as fish, birds, and mammals, possess this cord in their embryonic stages, but its place, in most, is taken later by a spinal column. Hence all animals, not included in the eleven branches already discussed, possess, either in their youngest stages or throughout life, a soft, flexible cord, or rod, known as a *notochord*, and consequently they are grouped together in one branch called the *Chordata*.

Moreover, when any animal so far noted has had a cavity in the body, it has had but one; for example, the hydra,

sea anemone, earthworm, and squid. In the hydra this cavity serves as a digestive tract. In the earthworm the cavity, or cœlome, as it is properly called, contains blood vessels, nerve cords and ganglia, and an alimentary canal (Fig. 142, *I*). Then we may say, in general, that invertebrates have one cavity in the body. On the other hand, in most of the members of the Chordata, and especially in the vertebrates, we find two cavities in the body (Fig. 142, *V*). One of these cavities contains the blood vascular system, a series of nerve ganglia, and the alimentary canal. This cavity corresponds quite closely to the one cavity found in the bodies of the invertebrates. The other cavity in the Chordata contains the brain and spinal cord, and we find nothing among the invertebrates to correspond with this cavity. It is well to bear in mind that the possession, by the Chordata, of a second cavity containing the brain and spinal cord constitutes a well-marked difference between this branch and all the invertebrates.

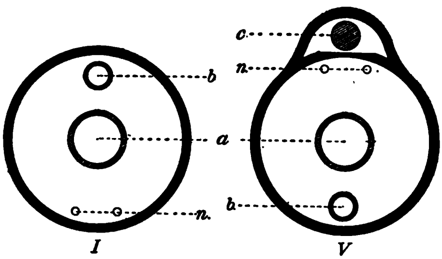

FIG. 142. — Diagrammatic cross sections of the body of an invertebrate (*I*), and a vertebrate (*V*). Note the one body cavity in *I*, and the two body cavities in *V*: *a*, alimentary canal; *b*, blood vascular system; *n*, nervous system; *c*, spinal cord.

Note that the two cavities in the Chordata are separated either by a notochord or by a series of bony segments that make up the spinal column. Note also that in whatever animal a spinal column is found it is always preceded by a notochord in the embryonic stages of that animal. With

these differences in mind we shall briefly discuss one class of the Chordata and then pass to the better-known vertebrates.

CLASSIFICATION OF THE CHORDATA

BRANCH XII — Chordata.
- Sub-branch — Urochorda.
  - *Class* — Urochorda or Tunicata.
    - Order — Ascidiacea.
      - Type of Order.
        - *Ascidia species* — **Sea squirt.**
- Sub-branch — Vertebrata.
  - *Division A — Acrania.*
    - *Class* — Acrania.
      - Type of Class.
        - *Amphioxus lanceolatus* — **Lancelet.**
  - *Division B — Craniata.*
    - *Class I* — Cyclostomata.
      - Type of Class,
        - *Petromyzon marinus* — **Lamprey.**
    - *Class II* — Pisces.
      - Type of Class.
        - *Perca flavescens* — **Perch.**
    - *Class III* — Amphibia.
      - Type of Class.
        - *Bufo lentiginosus* — **Toad.**
    - *Class IV* — Reptilia.
      - Type of Class.
        - *Crotalus horridus* — **Rattlesnake.**
    - *Class V* — Aves.
      - Type of Class.
        - *Passer domesticus* — **Sparrow.**
    - *Class VI* — Mammalia.
      - Type of Class.
        - *Lepus sylvaticus* — **Rabbit.**

XVIII. UROCHORDA AND VERTEBRATA

BRANCH XII. — CHORDATA (*continued*)

UROCHORDA

SEA SQUIRTS

Sea squirts. — The animals of this class are not well known to most of us. They are called ascidians as well as tunicates. They are marine animals, some species of which live a free-swimming life, while others are attached to rocks and are unable to move from place to place any more than the sponges. Like the sponges, many of them reproduce by budding, thus forming large colonies of individuals. Other species pass a solitary existence.

FIG. 143. — Sea squirt or ascidian.

In general, their bodies are barrel-shaped (Fig. 143), and covered with a flexible, leathery mantle or tunic, composed of two layers, the inner one of which usually contains many longitudinal and transverse muscles. In most species there are two

apertures to the body, one for the ingress and the other for the egress of water. From the latter opening the water is forced in a stream by the contraction of the muscular mantle. This habit gives them the common name, sea squirts.

Most of the ascidians possess a notochord only in the larval stage, losing it entirely as they become adults.

VERTEBRATA

Fishes, frogs, reptiles, birds, and mammals. — By far the greater number of animals belonging to the branch Chordata possess a spinal column, or backbone made up of bony segments called vertebræ, — hence the name vertebrates. The animals named at the beginning of this paragraph are familiar examples of vertebrates. The body of a vertebrate is divided into three regions: head, trunk, and tail. When limbs are present, there are never more than two pairs. In general, vertebrates have an internal skeleton. Some have also a partial external skeleton, as crocodiles, tortoises, and others, while many possess vestiges of an external skeleton represented by nails, horns, hair, feathers, hoofs, etc. Among vertebrates we find two kinds of respiratory organs, namely, lungs and gills. The land-living vertebrates and many of those living in the water are furnished with lungs, but the fishes and a few of the amphibians possess gills for breathing. In all except the lancelet there is a single contractile cavity, or heart. In all there is a system of blood vessels for the circulation of the blood.

LANCELET

Class. — Leptocardii (slender heart)

Lancelet. — The lancelet is the lowest vertebrate. It lives the life of a fish and somewhat resembles a fish in form,

but has no distinct head or heart and no eyes, legs, or fins. It is about two inches long and is found buried in the sand, along the shores of the Mediterranean Sea, North Sea, English Channel, our Atlantic and Gulf coasts, West Indies, coast of California, etc. It is transparent, flattened from right to left, and pointed at either end, hence its resemblance to the head of a lance.

The mouth, situated at the anterior end of the body, is simply a slit surrounded by hairlike filaments (Fig. 144).

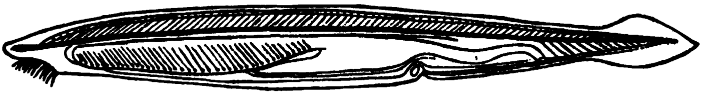

FIG. 144. — Diagram of a lancelet.

The blood is white and is made to circulate by the contractions and expansions of one of the arteries. No true heart is present. It has no backbone; but the notochord persists throughout life. Remember that in the sea squirts the notochord was present only in the larval stages. Here we find it existing throughout life.

The alimentary canal is very simple and nearly straight. The spinal cord lies just above the notochord, is slender and tapering. No true brain is present.

LAMPREYS

Class. — Marsipobranchii (saclike gills)

Lampreys. — They are long, smooth, and cylindrical, appearing much like eels. In fact, they are often called "lamprey eels." There are at least twelve species in the United States. They vary in length from one to two feet. The mouth is circular and is formed for suction. The interior

surface of the mouth of the common sea lamprey is covered with strong teeth and even the tongue is furnished with three large teeth. By means of the suckerlike mouth the sea lampreys attach themselves to the bodies of fish and, with the strong teeth, rasp off bits of flesh, at the same time sucking the blood.

Just back of the mouth, on each side of the neck, is a row of seven round holes (Fig. 145). These open into short tubes that lead to sacs in which the gills are situated. Con-

FIG. 145. — Sea lamprey.

sequently, in spite of the fact that the mouth of the lamprey is closed, the gills are bathed by fresh sea water that enters through the circular holes along the sides of the neck. They have no backbone, but the notochord persists through life. Attached to the sides of the notochord are small cartilaginous projections that suggest vertebræ.

Lampreys have a rudimentary brain, a spinal cord, and two eyes that are without eyelids but are covered by a thin transparent skin. The sea lampreys go up rivers in the spring, build rude nests out of small stones, and lay their eggs there. In the autumn the young return to the sea. The fresh-water lampreys in Cayuga Lake, N.Y., go up the small streams to lay their eggs.

The hagfishes which belong to this class and greatly re-

semble the lampreys are marine and are parasitic. They attach themselves to the bodies of fish and actually bore through the body walls and enter the abdominal cavities of their hosts. These and the lampreys are the only parasitic vertebrates.

XIX. FISHES

BRANCH XII. — CHORDATA (*continued*)

Class. — Pisces

THE fishes constitute the largest class of the vertebrates. They vary greatly in shape, size, and general appearance and are found everywhere over the earth. Three thousand species are now known to occur in North America alone.

AN EXAMPLE OF THE CLASS—THE PERCH

General form. — The body of the perch is long, deep, and thin from side to side and has a wedge-shaped head and a somewhat rounded tail ending in a fin, the principal organ of locomotion. There is no neck for the head is joined directly to the trunk. Therefore, the body is divided into three regions: head, trunk, and tail — the latter comprising that portion of the body beyond the anal opening.

Scales. — The body, except a part of the head and the fins, is covered with small scales that overlap each other like shingles and constitute the *exoskeleton*. The scales are horny outgrowths of the true inner skin, and they are covered with a thin, slimy membrane, the *epidermis*. The free, posterior edge of a scale is rounded, while the anterior edge, by which the scale is attached, is scalloped like the shell of certain mollusks.

Eyes. — There are two large eyes, one on each side of the head. They have no eyelids, but a thin, transparent skin

passes over the outside layer, or cornea of each eye. The pupil is large and conspicuous, and each eye is surrounded by a circular fold of skin and set in a protective socket.

Mouth and nostrils. — The perch can open the upper and lower jaws so wide that the mouth appears as a circular aperture almost as large as the circumference of the body. The perch lives upon smaller fish, worms, insects, etc., which are caught alive in its capacious mouth. The mouth is furnished with numerous small teeth that are present,

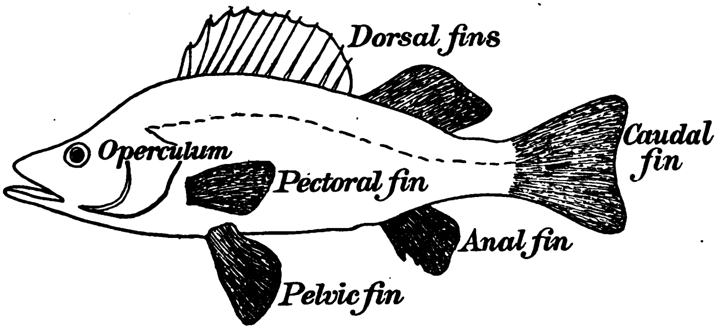

FIG. 146. — Diagram of a perch.

not only on both jaws, but on the roof of the mouth and roof and floor of the pharynx. The teeth are not strong enough to masticate the food to any extent, but are suited to hold the prey of the perch.

In front of each eye, on the head, are two openings, the *nasal apertures*, or *nostrils*. These do not communicate with the mouth as in the mammals, but lead to a pair of sacs, the *nasal sacs*, situated within the head above the roof of the mouth.

Fins. — The perch has eight fins of which four are borne in pairs, therefore known as the *paired fins*. The remaining

four are borne singly in the middle plane of the body and are therefore called *median fins*. The first pair of fins is borne, one on each side of the body, just back of the gill openings. These are the *pectoral fins* and correspond to the fore limbs of a mammal. The second pair, the *pelvic fins*, is placed a short distance behind the pectoral fins and on the ventral side of the body. These are homologous to the hind limbs of a mammal. There are two dorsal fins borne in a middle line on the back, one just behind the other. There is also a single fin, the *anal fin*, borne on the ventral side of the body in front of the tail fin. Finally, the tail terminates in a single wide fin, the *caudal fin* (Fig. 146).

A fin is simply an expanded fold of the skin with a supporting framework of spines, or rays. Some of the rays are segmented and are known as soft rays while others are stiff, unsegmented spines.

The gills. — On each side of the perch's head is a flaplike organ, the *gill cover*, or *operculum*. The posterior margin

FIG. 147. — Head of fish, with gill cover cut away to show gills.

of each gill cover is free and in a living fish, a stream of water is constantly flowing out through the opening between the gill cover and the body. Beneath each gill cover are four red comblike gills. Each gill consists of a double row

of fleshy filaments attached to the posterior and outer border of a slender bony arch. On the front and inner side of each arch is a row of teethlike projections, the *gill rakers*. Between the gills are long, slitlike openings, or clefts (Fig. 147).

The blood enters each gill from the lower end, passes out into the filaments, and returns to leave the gill through an artery from the upper end. Thus there is a constant flow of blood through each gill.

Manner of breathing. — Under natural conditions the perch's mouth and the gill covers are seen to open and close

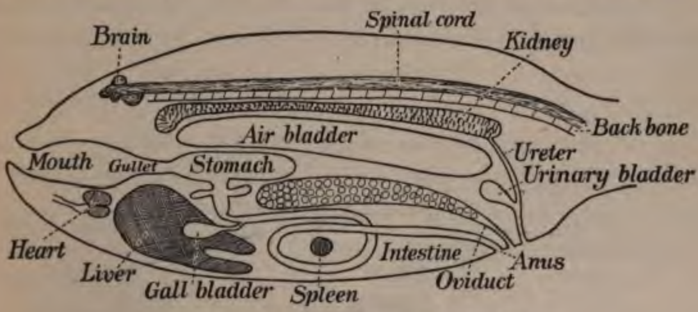

Fig. 148. — Internal structure of a fish.

alternately. During this action water is taken into the mouth, forced through the gill clefts and over the double rows of filaments, and thence out through the gill openings. Thus the gills are being constantly bathed with fresh water laden with oxygen. The current of blood through the filaments is separated from the water by a very thin, delicate membrane through which an exchange of oxygen and carbon dioxide readily takes place. The process is similar to that already described in the crayfish and mussel.

Alimentary canal. — The mouth and pharynx constitute a single large space that leads to the short, wide gullet.

The gullet opens into the stomach, which consists of an anterior region that extends straight back and ends blindly; a posterior region that leaves the anterior region at right angles near its middle; and three long, cylindrical, blind sacs, the cæca (Fig. 148). The intestine begins just back of the cæca and after one or two turns terminates at the anal opening. The liver lies in the anterior end of the body cavity and has on its posterior surface a gall bladder which empties its bile through a short duct into the anterior part of the intestine.

Circulatory system. — The heart of the perch lies between the gills and is in close relation to them. It is inclosed in

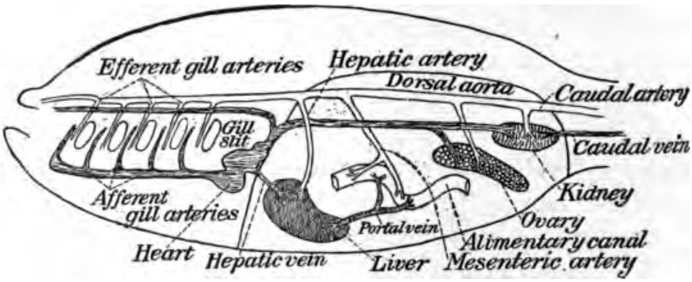

Fig. 149. — Circulation of a fish.

the pericardial cavity which is entirely separate from the main body cavity. The heart consists of three parts, the *sinus venosus*, the thin-walled *auricle*, and the muscular *ventricle*, placed in the order named, beginning at the posterior end. The ventricle pumps the blood from its anterior end through a large artery that sends a branch to the lower end of each gill. The blood then flows upward through the gill filaments and leaves them from the dorsal ends through arteries that finally meet in the median plane on the dorsal side of the body cavity and form the *dorsal*

artery, which, in turn, sends off branches that supply the different organs of the body. These branch arteries finally form minute capillaries that permeate all the tissues. The capillaries unite to form veins through which the blood is conveyed to the sinus venosus and from this into the thin-walled auricle and then into the ventricle, thus completing the circuit (Fig. 149).

Brain and spinal cord. — Looking at the brain from the dorsal side it is seen to consist of several divisions. The two hemispheres in front constitute the *cerebrum.* The *olfactory lobes* project from the anterior ends of the cerebrum and send the olfactory nerves forward to the nasal cavities. Posterior to the cerebrum are the two large *optic lobes,* the widest part of the brain. Behind these is the *cerebellum,* a single, undivided portion. Underneath and posterior to the cerebellum is the *medulla oblongata,* the enlarged end of the spinal cord which extends posteriorly through the bony tube formed by the dorsal projections of the vertebræ.

Plan of structure. — The fish presents an entirely new plan of structure. The nervous system is on the dorsal side of the body, while the nervous system of the invertebrate animals, for example, the earthworm, is on the ventral side of the body. Moreover, the main nervous system of the perch is inclosed in a long cavity on the dorsal side of the body. Below this cavity and separated from it is the large body cavity containing the alimentary canal. Therefore, in a cross section of the perch, two cavities appear, while in the cross section of the body of an earthworm only one cavity appears. As we pointed out earlier, these distinctions are characteristic of vertebrates and invertebrates.

How a fish swims. — In the dorsal part of the abdominal

cavity of the perch there is a long, thin-walled sac, the *air bladder*. It is filled with air and is evidently an organ for regulating the position of the fish in the water. The gas in the sac is compressed by the contractions of its muscular walls and the fish sinks. *Vice versa,* when the gas expands, the bladder becomes larger, the body lighter, and it rises. In some fishes that rest most of the time on the bottom there is no air bladder. In other fishes it serves as a lung.

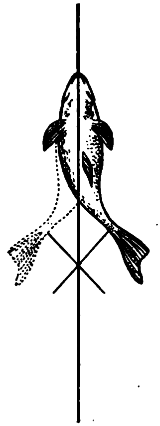

FIG. 150. — Diagram illustrating the locomotion of a fish. The tail describes the arc of an ellipse; the resultant of the two impulses is the straight line in front.

The posterior part of a fish is flexible and has a consequent freedom of motion not found in the more rigid anterior part. The tail and tail fin constitute the principal organ of locomotion. A quick sidewise stroke with the tail in one direction followed instantly by another stroke in the opposite direction forces the body forward in a straight line. The physical principles of this motion are shown in Fig. 150. In the movement of the fish the paired fins are used to balance the body and to ascend or descend in the water. The dorsal fins guide and steady the body in its progress. The tail fin is also used to guide the fish.

Reproduction and development. — The sexes are separate. The ovaries of the female lie above the intestine and open through the oviducts just behind the anal opening. The spermaries of the male communicate with the outside through the sperm ducts which open just back of the anus. The eggs are extruded from the body and are fertilized by the sperms which are set free in the water. The perch does not

look after its eggs. The young fish live upon crustaceans and small worms, but, in turn, may be eaten by larger fish.

Some fish scoop rude nests out in the gravel in which to deposit their eggs and then stand guard over them to protect them. The stickleback builds quite an elaborate nest for its eggs and the male assiduously cares for them.

Other Examples of this Class

Sharks, rays, sawfish, etc. — These examples are representatives of the lowest order of fishes. The sharks are

Fig. 151. — Hammer-headed shark. Note the five gill slits in the side of the neck.

the lowest in development of the fishes. At the same time, they are the fiercest animals of the sea.

In some sharks the body is protected by spiny processes, and in others the body has no protection at all; but very few animals dare to attack them. In general, the skeleton is cartilaginous, with no distinct bones as in the higher

fishes. There may be a deposition of bony matter in certain places — for example in the jaws and the vertebral column. The jaw is large and strong and furnished with many teeth. The mouth of most sharks is on the under side of the head some little distance back of the end of the snout. Consequently, a shark usually turns on its back when seizing its prey The gill openings are from five to seven in number, on each side of the neck (see the hammer-headed shark, Fig. 151), and are simply long, narrow, uncovered slits. The largest of all fishes is the great basking shark which attains a length of forty feet.

Fig. 152. — Sting ray, commonly called stingaree.

Some sharks reproduce by eggs which are of considerable size and furnished with a hard chitinous shell, often bearing several long filaments which seem to serve for attachment to seaweeds and the like.

In general, a ray, or skate, has a broad, flat body usually ending in a long, slender tail (Fig. 152). It swims close to the bottom of the sea for the most part, and feeds upon crabs, small fish, etc. It does not, like the shark, turn over to seize its prey, but swims quietly over a fish and quickly settles down upon it, holding it fast with the broad body and strong jaws.

Some rays are peculiar in having an electrical organ in the body that is capable, in the larger ones, of generating enough electricity to disable a man. It is probable that this is used in catching prey and in defending themselves from enemies. Other rays have long spines on their tails with which they can inflict serious wounds. These are the sting rays (Fig. 152).


FIG. 153. — Saw of a sawfish.

The sawfishes, which belong to the ray family, have long, sharklike bodies with the snout prolonged into a flat, horny blade beset with teeth on each side (Fig. 153). This saw varies from four to six feet in length and ten to twelve inches in width. It constitutes a formidable weapon which is used in attacks upon other fish and upon whales, toward which sawfishes are especially malignant.

Sturgeons, gar pike, etc. — The order of fishes represented by the sturgeons, gar pike, spoonbill, catfish, and bowfin seems to stand between the sharks and rays on the one hand and the bony fishes on the other. These few fishes, known as the ganoids, are the remnants of a host of similar fishes that lived in the Devonian and Carboniferous ages. They are notable for the bony plates that arm the outside of the body instead of the flexible scales on the bony fishes. Also for the lunglike structure and function of the air bladder. The air bladder in these fishes is connected with the gullet by an

open duct. Moreover, the air bladder is furnished with an unusual amount of blood and undoubtedly acts more or less as a lung, for both the gar pike and the bowfin often come to the surface, force out bubbles of air, and take in a fresh supply.

The sturgeons, which occur in many of the streams and lakes of the northern hemisphere, are the largest of the fresh-water fishes. Those of the lower Columbia River attain a weight of eight hundred to one thousand pounds. The skeleton, for the greater part, is cartilaginous with no small bones in the flesh. The body has five rows of large bony plates on the outside, but they are not contiguous and do not form a complete covering. The relish, caviar, is made from the roe or egg mass of sturgeons.

The gar pike, also known as the long-nosed gar, or bill-fish, is common in the United States, in lakes and rivers, from Lake Champlain to Texas. It has a long, slender body accentuated by a long, slender beak, composed of the two jaws, each of which is armed with teeth. It approaches the bony fishes in many respects. The body is covered with bony scales forming a complete armor and the skeleton is bony. It attains a length of about five feet.

Bony fishes. — The members of this order of fishes are distinguished from the preceding types by several characters chief among which is the possession of a bony skeleton. Indeed, this characteristic has given them the distinctive appellation of bony fishes. This order furnishes our most important food fishes, such as the herring, cod, salmon, mackerel, halibut, etc.

The mackerel is one of the most important food fishes. It is found from Labrador to North Carolina. They come in great schools, quite regularly in May and June of each

year, to the waters along the coast to spawn. At this time they are lean and not in good condition for catching. After spawning, however, they commence to move northward

FIG. 154.—Mackerel.

along the coast and at the same time begin to grow fat (Fig. 154).

The common herring (Fig. 155) is found on both sides of the Atlantic. On our coast it extends in abundance from Greenland to Massachusetts. The herring, like the mackerel,

FIG. 155.—Herring.

lives in deep water during the winter season, but comes to the coasts, in the spring, to spawn in shallow water. They come in immense numbers and at this time are caught by the million, in nets, off the coasts of Newfoundland and Labrador.

Of nearly equal importance with the mackerel and herring is the cod. Cod are found from Cape Hatteras to the Arctic Ocean, but are especially adapted to cold waters

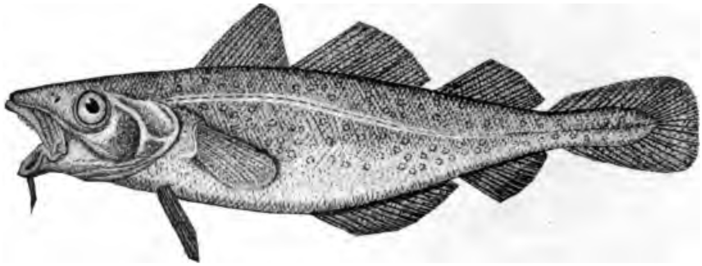

Fig. 156. — Cod.

and are most abundant in the northern seas. The cod weighs anywhere from ten to one hundred and fifty pounds and sometimes more. They are exceedingly voracious and live largely on other fish, especially herring (Fig. 156).

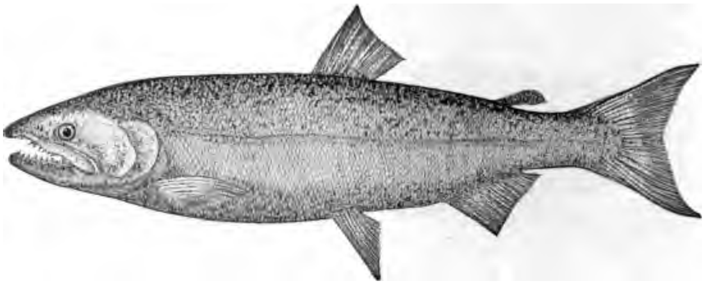

Fig. 157. — California salmon.

The salmon are *anadromous* fishes. That is, they live in the sea, but ascend rivers to spawn. The chinook (Fig. 157) salmon begins running up the Columbia River as early as March. The first ones to enter the river travel slowly,

but may finally reach the smaller tributaries of the river over a thousand miles from the sea. Here, on beds of fine gravel, they deposit their eggs. An individual salmon spawns only once, and as soon as the spawning is done both the males and females die.

"The game fish which has been most written about and which is, perhaps, best and most widely known among the anglers of the world is undoubtedly the brook trout or speckled trout." It belongs to the salmon family and inhabits cool, clear, and woody streams in the eastern part of Canada and our northern states, but is fast disappearing.

In addition to the fishes especially mentioned in the foregoing paragraphs, there are many others that form a very important part of our food supply. The perches, pikes, basses, anchovies, sardines, bluefish, halibut, mullets, and others are familiar food fishes. The black bass is an excellent food and game fish and is widely distributed in the streams and lakes of the eastern United States. The red snapper and the pompano are very important food fishes, especially along the Gulf coast. The sheepshead, so well known along the Atlantic and Gulf coasts, is a game fish and is of great commercial importance.

There are something over sixty species of the bony fishes that constitute the family of flying fishes. They are found in nearly all warm seas, usually appearing in schools near the surface of the water and sailing, or flying through the air. The largest species is found off the coast of southern California. This is the only flying fish inhabiting our Pacific coast north of Cape San Lucas. It is the largest flying fish known, attaining a length of eighteen inches and has the greatest power of flight of any member of the group. These fishes are enabled to sail through the air by means

of the greatly elongated and enlarged pectoral fins (Fig. 158). By means of vigorous, quick strokes of the tail and enlarged tail fin, the fish is able to jump from the water into the air. Then the large pectoral fins are spread and the fish floats on the air somewhat as a man borne by a parachute. Is is asserted that some of the larger species

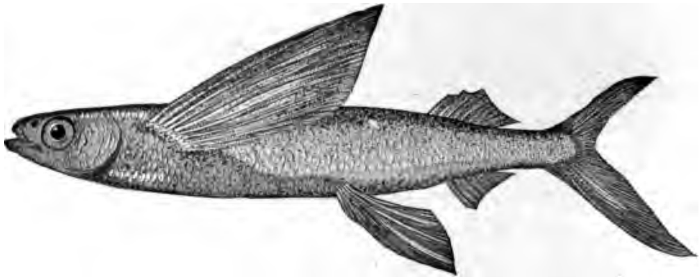

FIG. 158. — Flying fish.

actually vibrate the pectoral fins, thus producing a real flight capable of prolonged duration.

The bony fishes, for the most part, have large, conspicuous eyes, without eyelids, but covered with a thin, transparent skin. There are some, however, that live in the caves and underground streams of Illinois, Indiana, Kentucky, Tennessee, and Alabama, that have rudimentary eyes, — so rudimentary that in two or three species, at least, they are wholly valueless as organs of vision. The bodies of these fishes are colorless and translucent. One species lives in the Mammoth Cave of Kentucky.

The eels are bony fishes with long, cylindrical bodies bearing small inconspicuous scales. The common eel (Fig. 159) is found on both coasts of the Atlantic and in the rivers, lakes, and streams of the eastern United States,

from the Gulf of St. Lawrence to Texas and Mexico. Their habits are imperfectly known, but this much seems true. The young eels are born in the sea from eggs deposited by the mature female. In the spring these young eels ascend the rivers and streams, in which they remain until they are two or three years old. When grown and ready to spawn, they return to the sea.

FIG. 159. — Eel.

The electric eels, so-called, belong to another order of fishes. They are eel-like in shape but are not true eels. They possess powerful electric batteries.

Lung fishes. — All of the sharks, rays, and bony fishes breathe by means of gills. The air bladder, when present in these fishes, seems to function only as a hydrostatic apparatus. But in the ganoids, represented by the bowfin, gar pike, sturgeon, and spoonbill, the air bladder certainly functions, to some extent, as an organ of respiration. So we find that the ganoids foreshadow, as it were, fishes which possess true lungs in which the blood is purified by the exchange of gases. There are, at least, three very interesting species of fishes, known as the lung fishes, in which the air bladder is modified into a fairly well-developed lung. One species is found in the fresh waters of Queensland, Australia, and is called Ceratodus, or "Burnett Salmon." It grows

to the length of four or five feet, and the body is covered with scales (Fig. 160). It has gills like other fishes, but, in addition, the air bladder is modified into a respiratory organ that opens into the pharynx, like the lungs of mammals. The blood flows to this lung and is there purified exactly as in the higher animals. The Ceratodus lives in

FIG. 160. — Australian lung fish.

still pools that become very stagnant during the dry summer season, and it survives only by rising to the surface now and then to take fresh air directly into the lung.

Of the other lung fishes, one species lives in South Africa and one species is found in the rivers of South America. In both of these species the modified air bladder, or lung, is divided into two lobes, and in this respect they differ from Ceratodus. The walls of each lobe are supplied with many blood vessels filled with venous blood which is brought to the lung by a special pulmonary artery to be purified. The species in South Africa also lives in pools which dry up during the hot season. Before the water wholly evaporates the fish descends into the mud and hollows out a place in which it lies until the rains come again.

General character of fishes. — For the first time we now meet with animals that have a jaw bone and bony skeleton. The skeletons of all fishes are not bony, for some have cartilaginous skeletons. Moreover, the fishes have a true skull, which, however, in some is rather rudimentary. The

brain of fishes is well developed and the blood is red but cold. They have a true but single heart consisting of an auricle and ventricle. Most fishes breathe only by means of gills. The gills vary in number and structure in different orders, but are alike in their general structures in the bony fishes, of which those described in the perch may be taken as an example.

Habits and adaptation to environment. — Fishes are preëminently adapted to an aquatic life, and all live in the water. The body, in most cases, is of such a form that it "cuts" the water and thus offers the least resistance.

For obtaining air from the water, all fishes are furnished with some kind of gills. This is a direct adaptation to their environment. Again, the fishes are quite large animals and, for the most part, are very active. Consequently, there is a great deal of the tearing down and building up processes going on in the body. As a result, there must be some adaptation or arrangement whereby the blood may have free, constant, and full access to air. To provide for this we have already seen how the mouth, pharynx, and gill covers are so constructed that a current of fresh water, laden with air, is kept constantly flowing over the gills. Moreover, the gills are not of one piece, but are composed of a great number of filaments to provide more space whereby the blood may come in contact with more water. Again, the limbs of fishes, if the fins may be called such, are admirably adapted for locomotion in the water, but totally useless on land.

Some fishes are protected from their enemies by their resemblance to objects in the sea. One of the anglers is said to counterfeit very remarkably a rock with its attached growth of seaweed and sea animals. Undoubtedly this resemblance also serves as a ruse for capturing its prey.

Some fishes are clothed with spines as a protection from their foes. Others are found in company with certain jellyfishes where they receive the protection of the stinging cells. Others creep within the shells of certain mollusks. Among the bullheads and catfish, the first ray of the dorsal and pectoral fins is developed into a sharp, stiff, serrated spine which inflicts severe wounds. In the members of two genera of this family of fishes a poison gland is connected with the pectoral spine.

Economic importance of the fishes. — The commercial importance of this group of animals is very great. The place that the fishes fill in the food supply of the American people is so important that the United States government, long ago, established the United States Fish Commission (now called the Bureau of Fisheries) and annually appropriates large sums of money to enable the members of this commission to study the habits, distribution, food, and methods of preservation of our most important food fishes. The fast-failing supply of many of our most important food fishes has caused the government to establish extensive fish hatcheries at favorable locations. From these hatcheries thousands of young fish and eggs are sent to the different ponds, lakes, and streams of the United States and even the oceans bordering this country. For example, the cod is propagated artificially on a more extensive scale than any other marine fish. The number of cod fry liberated by the United States Fish Commission in 1905 was 169,577,000. The common whitefish may be taken as an example of the work done by the Commission in maintaining the supply of fresh-water fishes. In the fiscal year of 1905 the United States Fish Commission hatched and planted 268,405,000 whitefish fry.

The cod fishery employs more men and more vessels than any other fishery in the United States. There are hundreds of vessels and thousands of men employed in catching cod. The annual catch amounts to more than ninety-six million pounds, with a first value of about two million dollars.

The herring fishery is also very extensive. These fishes go in immense shoals, a single shoal sometimes covering several square miles and containing two or three billion individuals. It is estimated that between one and two billion pounds of herring are taken every year.

The annual value of the salmon taken on our Pacific coast, including Alaska, exceeds thirteen million dollars. The two species, chinook and blueback, comprise the greater portion of the catch represented by this vast amount, the catch of the other three species being insignificant in comparison.

The common whitefish which is an inhabitant of the Great Lakes region, from Lake Superior to Lake Champlain, furnishes a food product valued at nearly three million dollars a year.

Fig. 161. — Sea horse.

The New England catch of mackerel amounts to about six million pounds, valued at about four hundred thousand dollars, and sixteen thousand barrels salted, valued at one hundred and eighty thousand dollars.

The halibut, menhaden, anchovy, sardine, trout, red snapper, pompano, sturgeon, bluefish, and scores of others swell the aggregate value of the food fishes of America to almost fabulous figures.

CLASSIFICATION OF THE FISHES

Class — Pisces.
- *Subclass* — Elasmobranchii.
  - Order — Selachii.
    - Types of Order.
      - *Sphyrna zygæna* — Hammer-headed shark.
      - *Raja erinacea* — Ray.
      - *Carcharhinus glaucus* — Blue shark.
      - *Trygon sabina* — Sting ray.
      - *Torpedo occidentalis* — Electric ray.
      - *Pristis pectinatus* — Sawfish.
- *Subclass* — Teleostomi.
  - Order — Chondrostei.
    - Types of Order.
      - *Acipenser sturio*, *Acipenser rubicundus* } Sturgeons.
      - *Scaphirhynchus platorhynchus* — Shovel-nosed sturgeon.
  - Order — Holostei.
    - Type of Order.
      - *Lepidosteus osseus* — Gar pike.
  - Order — Teleostei.
    - Types of Order.
      - *Oncorhynchus tschawytscha* — Chinook salmon.
      - *Gadus callarias* — Cod.
      - *Clupea harengus* — Herring.
      - *Scomber scombrus* — Mackerel.
      - *Anguilla chrysypa* — Eel.
      - *Cypsilurus californicus* — California flying fish.
      - *Perca flavescens* — Perch.
- *Subclass* — Dipnoi.
  - Order — Monopneumona.
    - Type of Order.
      - *Ceratodus forsteri* — Lung fish.
  - Order — Dipneumona.
    - Types of Order.
      - *Protopterus annectens*, *Lepidosiren paradoxa.* } Lung fishes.

XX. FROGS, TOADS, AND SALAMANDERS

CHORDATA (*continued*)

Class III.—Amphibia (animals with double lives), (amphi, double; *bios,* life)

As a class, the amphibians, of which there are over a thousand known species, present a great diversity of forms. No general statement can be made regarding this class of animals to which exception cannot be found. The great majority of the amphibians possess legs and have smooth skins — not covered with scales like the snakes and lizards. A typical amphibian lives a double life, as it were. It begins life in the water, in the form of a fishlike animal without legs but with a large tail and a pair of external gills. Later, the gills are replaced by lungs, the tail is absorbed into the body, and four functional legs appear. At this stage of its existence one species of amphibian may live on land while another species may confine itself wholly to an aquatic life.

AN EXAMPLE OF THE CLASS—THE GREEN FROG

The body. — The body of the frog is short and wide and without a tail. It is divided into two regions only, — the head and the trunk. Like the perch, there is no distinct neck, yet there is one neck vertebra between the head and trunk which shows that the neck of the higher vertebrates is just beginning to make its appearance in the frog. The

body of the frog is covered with a smooth, moist, clammy skin devoid of scales. The color of the skin usually accords with the surroundings and may change to suit new environments. The color is due to cells of pigment in the skin.

Eyes. — The two eyes are very prominent and protrude from the head. Each one is furnished with an upper and an under lid. The upper lid is thick and not capable of much movement, but when the eye is withdrawn, this lid drops down over it in a sort of mechanical way. The under lid is thin and can be drawn over the eye. It is called the nictitating membrane.

The hearing organs. — Back of each eye is a conspicuous, round area, the *eardrum* or *tympanum*. An elastic rod, the *columella*, one end of which is attached to the inner surface of the tympanum, extends to the inner ear situated within the skull. When sound waves strike the tympanum and cause it to vibrate, the vibrations are transmitted by the rod to the inner ear, which is the true organ of hearing. Each ear communicates with the mouth through the Eustachian tube.

The nostrils and manner of breathing. — In front of the eyes and above the mouth are the two nostrils. Each opening is furnished with a valve so that it can be tightly closed. Both nostrils communicate directly with the mouth.

Within the body cavity of the frog are two pink-colored lungs of considerable size that communicate with the mouth through the windpipe. They are filled with air spaces, surrounded with walls permeated with capillaries containing blood. It must be noted, however, that the lungs of the frog are not perfect organs of respiration and are aided in this work by the skin and the mucous membrane of the mouth and pharynx.

Air is taken into the mouth through the nostrils which are then shut by means of the valves. At this time the floor of the mouth is bulged downward, showing that the mouth is full of air. By an action similar to that of swallowing, in which the floor of the mouth is raised, the air is now forced into the lungs. The air is expelled from the lungs by the contractions of their walls aided by the muscular contractions of the walls of the abdomen.

The skin is furnished with many minute blood vessels and aids in the process of respiration.

The mouth and tongue. — The mouth of the frog is large, and the jaws can be opened very wide. There is a row of small teeth on the upper jaw and a few on the roof of the mouth but none on the lower jaw. These serve merely to hold the prey, not to masticate the food.

The tongue is attached to the mouth by its anterior end, thus leaving the posterior end free. This arrangement enables the frog to extend its tongue outside of the mouth nearly its whole length, since it is attached at the front part of the mouth. The tongue is covered with a sticky, mucous secretion.

Legs and locomotion. — The frog has four well-developed legs, the hind pair being much the longer and stronger. The thighs of the hind legs are furnished with strong muscles and the hind feet are long, broad, and webbed.

The frog has three methods of locomotion — walking, swimming, and leaping. Under certain conditions — for example, when climbing up a sharply inclined surface — this animal moves in a slow, awkward walk. Its main method of locomotion on land is by long and powerful leaps with the hind legs. In water the frog is a model swimmer. The front legs take no active part in this method of loco-

motion, the body being propelled by the powerful strokes of the hind legs aided by the webbed feet.

Alimentary canal. — The mouth opens into the wide gullet which, in turn, leads to the long stomach. The stomach narrows posteriorly into the intestine, which makes several turns and ends in an expanded portion, the *cloaca* (Fig. 162). The kidneys, oviducts, and bladder open into the cloaca. The lobed liver communicates with the an-

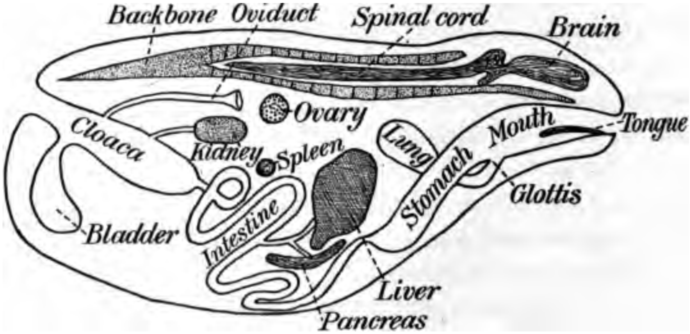

FIG. 162. — Internal structure of a frog.

terior part of the intestine through the duct of its gall bladder. A pancreas is also present, the duct of which opens into the duct of the gall sac.

Excretory organs. — There are two reddish brown kidneys lying on the dorsal side of the body cavity near the cloaca. Each one opens into the dorsal side of the cloaca through a tube, the *ureter*. The bladder is found on the ventral side of the cloaca (Fig. 162). The lungs and skin do their share of excretion by getting rid of the carbon dioxide from the blood.

The circulation of the frog. — The frog has a closed circulation and the heart is the principal organ of the circu-

latory system. It is composed of three principal parts, the muscular ventricle and two thin-walled auricles. The blood is sent out from the anterior end of the ventricle through a single artery, which gives off three branches on each side. Four of these pass to different parts of the body and end in capillaries The capillaries unite to form veins through which the blood returns to the right auricle of the heart. Of course this blood is impure and charged with carbon dioxide. The remaining two branches carry blood to the lungs and skin, where it is purified and returned to the left auricle. The auricles empty their blood, both pure and impure, into the ventricle. But by a complicated system of valves and by the manner in which the single artery branches the two kinds of blood mix but little and the purest blood is sent to the head, the next best to the different parts of the body, and the impure back to the lungs.

The food and method of obtaining it. — The frog feeds upon living, moving animals only; as worms, moths, flies, beetles, etc. These are caught, while they are in motion, on the end of the tongue as it is darted from the mouth with great rapidity. The sticky, mucous secretion on the tongue serves to hold the prey. The food is swallowed whole and digested at leisure.

Reproduction and life history. — When mature, the eggs are set free in the body cavity and finally find their way into the mouths of the oviducts. In the passage through the oviduct each egg becomes coated with a gelatinous material which swells greatly when the egg reaches the water. The eggs are deposited in large, irregular, jellylike masses, usually near the edges of pools and very often about the stem of some plant (Fig. 163). After a number of warm days each egg hatches into a black, wiggling object with an

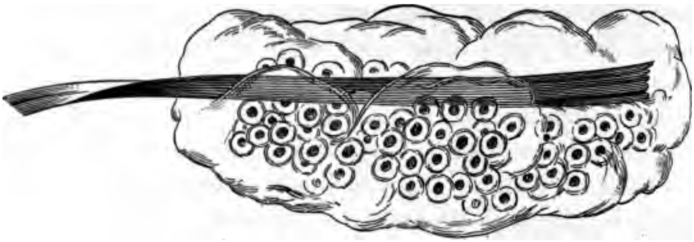

FIG. 163. — Eggs of frog.

indistinct head and a wide tail. This form is known as a "tadpole," or "polliwog." The tadpole lives in the water attached, part of the time at least, to the jellylike mass or to water plants, by an adhesive apparatus, or "holder" on the head near the mouth. A little later, the tadpole becomes a free-swimming organism. It breathes by means of small external gills on each side of the head (Fig. 164), and eats minute particles of vegetable matter found in the water. Later, the external gills disappear and are replaced by internal ones. In a few weeks, the hind legs begin to appear and then the front legs, while, at the same time, the tail becomes shorter and shorter. In

FIG. 164. — Tadpole, highly magnified, and showing gills (A).

the meantime the gills disappear and lungs begin to form. Finally, when the legs are all formed and the tail has disappeared and the lungs are fully developed for breathing air, the little frog climbs out on land or floats at the surface of the water with the eyes, nostrils, and mouth projecting into the air.

Habitat and habits. — The frog is found near ponds, pools, or streams of water. In a quiet walk along the banks of a stream, they may be seen leaping into the water from their resting places in the grass, where they have been in search of food. They are obliged to remain near the top of the water in order to obtain air and usually float at the surface with the head out of the water. In spring they become very musical and congregate in ponds to lay their eggs. After the eggs are laid they scatter to different places to avoid overcrowding and to insure a food supply. In the winter they dive to the bottoms of ponds and burrow into the mud. Here they pass into a state of stupor, with the eyes closed, and the organs of the body inactive. In this condition they are said to be *hibernating*.

The common toad. — The toad differs from the frog by the total absence of teeth, by the rough, warty skin, and by the fact that it lives on land, going to the water only in the spring to lay its eggs. It must be said, however, that toads require damp, moist places in which to live. They are often seen in great numbers after a shower because they delight in a cool, moist atmosphere, and come out from their hiding places to enjoy it. They usually remain hidden during the day and come out at dusk and at night to catch insects in the same manner as the frog, for the tongue of the toad is similarly constructed. The alimentary canal, excretory and circulatory organs are similar to those of the

frog. The life history of the toad is like that of the frog except that the eggs of the toad are deposited in long, coiled strings in shallow water. The eggs are black and spherical and are held together and surrounded by a string of transparent gelatinous material.

Molting of the toad. — From time to time, in its life, a toad sheds its skin much after the manner of a molting caterpillar. "Without any preliminary symptoms or loss of appetite or liveliness, the body makes a few twisting motions, the back is now and then curved, and the skin splits down the middle line." After the skin has been

FIG. 165. — Surinam toad.

partly peeled from the body, the toad gets the free end into its mouth, gradually slips out of the skin backwards, and finally swallows it. The new skin is usually light in color and is wet and shining but soon becomes dry and hard.

Hibernation. — When the toad feels winter coming on, it digs a hole in the earth with its hind feet — backing into it as it digs — and lies at the bottom, in a deep sleep, until spring returns.

Toads with interesting habits. — The surinam toad which lives in Dutch Guiana, South America, is exceedingly interesting because of the remarkable manner in which its eggs are cared for and hatched. Just previous to the egg-laying period, the skin of the back of the female is specially prepared by nature for a remarkable proceeding. It becomes very thick, spongy, and soft. The eggs are taken by the male toad, and one by one are *imbedded in the skin on the back of the female,* so effectually that the skin closes over them, and each egg becomes partially encysted and retained in a cell of its own. There they remain until they are fully incubated, the tadpole stage is passed, and a tiny, but perfect toad emerges *from the skin of its mother's back!* Therefore, the surinam toad does not pass its larval life in the water, but in the adult stage it is thoroughly aquatic and has the hind feet webbed (Fig. 165).

Other Amphibians

The cæcilians. — These are the lowest of the amphibians. They are wormlike in appearance and bear little resemblance to vertebrates. They have no legs or fins and many of them are blind, with the eyes hidden beneath the skin. They inhabit the tropical regions of Mexico, Central and South America, Africa, Asia, and Australia, but none are found in the United States. These amphibians are of burrowing habits and possess strong, solid skulls because they burrow entirely with their heads.

Necturus. — The necturus has a long, rather depressed body, reminding one of a reptile. It is found in the rivers of the upper Mississippi Valley and in the Great Lakes and the lakes of central New York. The body reaches a maximum length of sixteen inches and has two pairs of short legs. It has three bushy red gills on each side of the head and is especially to be noted as an amphibian that *retains its gills throughout life.*

The siren, or "mud eel," which is found abundantly in the ditches of the South Carolina rice fields and in fact

FIG. 166. — Mud eel or siren: *G*, gills.

occurs throughout the southern states to Texas, is another amphibian that retains its gills throughout life. It has a dark-colored, cylindrical body about two feet long, but has only one pair of limbs, the front pair (Fig. 166).

Hellbender. — The "hellbender," "water dog," or "alligator," as it is variously called, is a large amphibian

from eighteen to twenty inches long, found in the Ohio River and its tributaries. It is a repulsive but harmless animal. Closely allied is the giant salamander of Japan, which attains a length of three feet.

The congo snake. — There is an amphibian found in the swamps, muddy streams, and ditches of the southeastern states that is known as the "congo snake" or "congo eel." It has a slender, eel-like body about two feet long with two pairs of small, short legs. It is erroneously thought to be venomous.

Salamanders. — No true salamanders are found in the United States. These animals proper are found in Euro-

Fig. 167. — Spotted salamander.

pean countries. What are called salamanders in the United States are small amphibians mostly belonging to the genus Amblystoma. The spotted salamander, which has a series of round, yellow spots along each edge of the back, is about six inches long, and is common in the eastern United States (Fig. 167). It is terrestrial, frequenting moist places beneath logs, leaves, etc. Like the toad, it passes through remarkable changes in its development, — the larva possessing gills. The adult, when handled, may eject a stream of transparent fluid like a toad. This fluid is poisonous.

Some of the members of the salamander group are known as newts. These small amphibians frequent ditches and sluggish water and subsist mainly upon insects and worms. Although usually considered venomous, they are harmless. Some salamanders are aquatic and some terrestrial. Those living in water have flattened tails, while the terrestrial forms have cylindrical tails.

Most of the land salamanders bring forth their young alive, while those inhabiting the water lay eggs which are usually attached to a submerged plant stem.

Frogs. — The most common frogs in the United States are the bullfrog, green frog, and wood frog. Of these the green frog is the most abundant and the noisiest. It is only about two and a half inches long, but what is lost in size is gained in numbers. They are the first to herald the coming of spring, and the soft, evening air seems full of the piping choruses that issue from dozens of these little amphibians inhabiting every swamp and pond in the neighborhood.

The bullfrog is so well known that it hardly needs description. It is noted for its large size and great, thick thighs which furnish such tempting delicacies for epicures. It varies from five to six inches in length and has a deep bass voice.

The bullfrog is always found near water into which it can jump when disturbed. On the other hand, the little wood frog, which is only about one and a half inches long, lives in the woods and depends for safety upon its resemblance to dead leaves. It can leap several feet at a time, but is soon exhausted by its efforts and is easily captured.

Tree toads. — We have in the United States several species of amphibians known as tree frogs and tree toads. As a matter of fact, these little animals belong neither to

family of true toads or frogs but fall in a family by them-
ves. The tree toads (Fig. 168) of our country are noted
their loud voices. It is these that we hear piping so
illy in the early
ing. In the even-
, after a rain, the
d, clear piping of
little tree toad,
own as *Hyla versi-
or*, is almost in-
iably heard. It
called versicolor,
ause, like many
er tailless amphib-
s, it possesses the
ver of changing
shade, or tint of
skin. Ordinarily,
is gray above
h dark, irregular
tches, greatly re-
bling the bark of
es (Fig. 169), on
ich it lives. On

FIG. 168. — Tree toad (*Hyla versicolor*). Note the suction disks on the toes.

under sides of all of its toes and fingers are small
esive disks by which it is enabled to cling to the trunks
l branches of trees. It is also able to leap two or three
t from branch to branch.

Characteristics of the group. — To sum up, the Amphibia
animals that, in general, live a double life. That is,
part of their lives, the first part, is passed in the water,
h few exceptions, while the later, or adult stage, is usually

passed on land. Since the early, or larval stage, of these animals is passed in the water, most of the larvæ are furnished with gills for breathing. Adult amphibians that live in the water all their lives retain the gills throughout life. Those, however, that live on land during the adult stage lose the gills, and have lungs instead. They differ from the fishes in having segmented limbs instead of fins. They are cold blooded. The majority have smooth, scaleless skins.

Fig. 169. —Tree toad on the bark of a tree.

Adaptations to environment. —Note that the tadpoles of amphibians which live in the water have gills to suit such an environment; but when dry land is substituted for water, the gills are lost and lungs appear. Again, the necturus and the siren that live in the water all their lives retain the gills throughout life, as best suited to such an environment.

Tadpoles of frogs and toads are provided with broad, flat tails for swimming; but the adult frogs and toads are tailless. Many frogs are excellent swimmers, however, because of their webbed toes and the adaptations of their legs to such a purpose. The webbed toes of some species of the tree frogs of the Malaysian Islands (Fig. 170) have become much enlarged and adapted to quite a different

purpose; namely, that of parachutes to aid in their leaps from branch to branch. The little tree toad of our country, of which we have spoken, has its toes and fingers provided

FIG. 170. — Malaysian tree frog.

with adhesive disks which enables it to cling to vertical surfaces and, hence, adapt it to an arboreal life.

Relationship and significant features of this branch. — The Amphibia are a group of animals standing between the fishes and the reptiles. The fishes, on one hand, are water animals; the reptiles, on the other hand, are land animals; while the amphibians, in between, are both. That is, the greater number of them live in water during the first part of their lives, and on land, the latter part.

The Amphibia within themselves are very interesting, as showing a gradual transition from water-breathing to air-

breathing animals. The lower of the amphibians — the necturus and the siren — pass their entire lives in the water and possess gills in the adult stages. The higher amphibians — toads and frogs — live on land in the adult stage, and possess lungs.

Among the so-called salamanders, there is, at least, one species that, within its own lifetime, may pass in transition from the lower to the higher types of the Amphibia. That is, the individuals of this particular species of salamander may, under stress of circumstances, change from a form that possesses external gills and is fitted for an aquatic life to a form that possesses lungs and is fitted for life on land. In either of these stages, this amphibian, the axolotl, breeds successfully and reproduces its kind. When in the aquatic form, the axolotl has the structure, habits, and habitat of the lower amphibians; but when it assumes the land form, it has the structure, habits, and habitats of the higher amphibians. This remarkable twofold life is evidently an adaptation to the environment of this animal. When the ponds in which it lives are about to dry up, it assumes the land form, and in this stage it has long been known as the spotted salamander.

Economic importance of the Amphibia. — As a group, the Amphibia are not of great economic importance, for there are only two species that are considered to possess any significant economic value, namely, the bullfrog and the toad. The bullfrog may be found in season in the markets of all of our large cities. In France and in southern Europe, the European green frog is reared in "froggeries" and used extensively as an article of food. From a purely agrarian point of view the common toad has a greater economic value than any other amphibian.

The toads eat only living, moving insects, centipeds, sow bugs, etc. They destroy great numbers of noxious insects in gardens and fields. Professor Kirkland found by examining the stomachs of many toads that "a single toad in one season might destroy cutworms which otherwise would have damaged crops to the extent of $19.88." The toad is of conspicuous service to all agriculturists, but especially so to gardeners, who should try to collect toads and keep them in their gardens.

CLASSIFICATION OF THE AMPHIBIANS

Class III — Amphibia.
- Order — Urodela.
  - Types of Order.
    - *Necturus maculatus* — Necturus.
    - *Siren lacertina* — Mud eel.
    - *Amphiuma means* — Congo snake.
    - *Amblystoma punctatum* — Spotted salamander.
    - *Megalobatrachus japonicus* — Giant salamander.
    - *Cryptobranchus alleghaniensis* — Hellbender.
- Order — Anura.
  - Types of Order.
    - *Bufo lentiginosus* — Toad.
    - *Pipa americana* — Surinam toad.
    - *Rana catesbiana* — Bullfrog.
    - *Rana palustris* — Marsh frog.
    - *Rana clamitans* — Green frog.
    - *Rana sylvatica* — Wood frog.
    - *Hyla versicolor* — Tree toad.

XXI. SNAKES, TURTLES, LIZARDS, CROCODILES

CHORDATA (*continued*)

Class IV. — Reptilia (creeping animals)

THE reptiles are cold-blooded animals that differ markedly from the amphibians in many important respects. The life history of a reptile is comparatively simple, for no reptile passes through the remarkable changes that are characteristic of most of the amphibians. The majority of reptiles possess an outside covering of scales, or horny plates, or, in the case of turtles, of a bony box, while amphibians, for the most part, are smooth skinned. Superficially, some reptiles resemble certain amphibians and *vice versa*, some amphibians are often mistaken for reptiles.

AN EXAMPLE OF THE CLASS—THE SIX-LINED LIZARD

External features. — The body is long, slender, and more or less cylindrical. It presents four divisions — head, neck, trunk, and tail, all of which are clothed with scales. This contrasts quite strongly with the smooth, short, broad, and tailless body of the frog. Like the frog, the lizard has four legs, but they are more nearly equal in size and none of them are fitted for leaping. Each leg terminates in five digits furnished with claws.

The eyes. — The eyes are conspicuous, but they do not protrude. Each has an opaque upper and under lid and a nictitating membrane. The latter may be drawn completely

over the eye and when not in use, is folded in the inner corner of the eye.

The ears and nostrils. — Posterior to the corners of the mouth are the conspicuous tympanic membranes of the ears. The nostrils are situated on the anterior end of the head and open into the mouth.

The mouth and teeth. — The mouth is a wide, slitlike aperture extending nearly from ear to ear around the anterior border of the head. The jaws are not dilatable like those of a snake, but each one is furnished with a row of small, conical teeth. On the floor of the mouth is the narrow, fleshy tongue with a forked extremity.

Locomotion. — Some lizards are very swift of movement and quickly scurry out of sight when alarmed. Others are sluggish of movement because the legs are weak and unable to bear the weight of the body. The digits of the lizard's hands and feet end in sharp claws which enable it to climb trees and run nimbly along old logs, rails, etc.

Food and manner of eating. — Lizards live largely upon insects which they catch alive in their capacious mouths. Dr. Shufeldt gives an interesting account of the manner in which the little American chameleon ate a butterfly. He says, "I was so fortunate, not long ago, as to catch one in the act the instant after he had made a successful spring upon rather a large butterfly. The body of the insect was in his mouth while the wings were violently flapping the sides of the lizard's face. The reptile would clinch his jaws together spasmodically two or three times, shutting his eyes with a very tight squeeze every time he did so. At last his prey was silent, when with a few energetic kicks he tore off the creature's wings and disposed of its body *sans cere-monie.*"

Scales. — The whole body is covered with scales which are true epidermal structures. The scales on the dorsal side of the head are large and shieldlike. Those on the dorsal side of the abdomen are small and hexagonal, while those on the ventral surface are large, rectangular in shape, and arranged in eight longitudinal rows. The scales on the tail are keeled and arranged in regular transverse rows which give a ringed appearance to this organ.

The digestive system. — The mouth opens into a slender gullet which leads to the stomach. Following the stomach

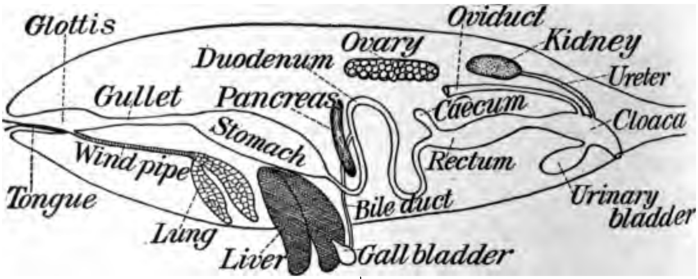

Fig. 171. — Internal structure of a lizard.

is the small intestine, or *duodenum*, which is more or less coiled. The duodenum is succeeded by the large intestine, or *rectum*, which joins the *cloaca*, the dilated end of the alimentary canal. A two-lobed liver lies in the anterior part of the body cavity and has a gall bladder which empties into the duodenum through the bile duct. A pancreas is situated in the loop between the duodenum and stomach. At the point of union between the small and large intestine, the latter is produced into a short, blind sac, the *cæcum* (Fig. 171).

Other Members of this Class

Snakes

Garter snake. — This small, harmless snake is found everywhere in the United States and will serve as a type of the snakes. It has a long, cylindrical body, tapering

Fig. 172. — Garter snake shedding its skin. Note the old loose skin just back of the head.

toward the tail (Fig. 172). The head is fairly distinct, but no limbs are present. The body of the snake is covered with scales that overlap like those of a fish. They differ from those of a fish in being true epidermal structures. The

scales on the ventral side of the body are large and extend transversely across the width of the body. These scales are known as *scutes*. Each scute is attached to a pair of ribs and, moreover, is fastened, or hinged at its anterior edge, while the remaining portion of the scale is free. The scutes are the main organs of locomotion. The free edges of the scutes are brought forward and downward, where they catch against the irregularities of the surface, and when forcibly returned to their normal positions close to the ventral side of the abdomen, force the body forward. If an individual should be placed on a smooth surface, like glass, it would be unable to crawl because no inequalities of surface would be presented for the scales to push against.

The eyes of the garter snakes have no lids, but are protected by the skin that passes over them, which is transparent and somewhat thickened just over the eyes. The absence of eyelids accounts for the cold, stony stare of snakes. No external ear is present. In fact, no snakes have external ears.

The tongue is forked, and the two halves of the lower jaw are loosely united in front, while the whole jaw is loosely hinged to the head by means of an intermediate bone, the *quadrate*. This arrangement allows the mouth to be greatly dilated for swallowing its prey. The teeth all point backward and are for the purpose of holding its prey, and not for chewing, because the food is swallowed whole.

Pythons. — It is said that some pythons reach the extreme length of thirty feet, but probably twenty feet is nearer the average. They are found in the tropical portions of Asia, Africa, and Australia. A python has a prehensile tail, and by means of this, clings to the branches of trees,

while the remainder of the body is left free to wrap around its prey. It is important to note that pythons have vestiges of hind limbs.

The boa constrictor and anaconda are two very large snakes that are found in South America. The anaconda is said to attain a length of thirty feet.

Cobra of India. — With but one exception, this is the most deadly animal in existence. Yet it is certainly handled

FIG. 173. — Copperhead.

with impunity by those strange men of India, the jugglers or snake charmers. The fangs and poison apparatus are much like those of the rattlesnake except that the fangs of the cobra are permanently erect, while those of the rattlesnake are erected under excitement. The bite of the cobra

is almost sure death, and thousands of the natives die from it yearly. The poison instantly affects the whole system and causes great pain.

Copperhead. — This is a common poisonous snake of the United States. It is found from New England to Florida, east of the Mississippi, principally in mountainous districts. The head of this snake is copper colored, hence the name. Its venom is second in virulence to that of the rattlesnake. In the different localities of its range, the copperhead is known as the deaf adder, pilot snake, and upland "moccasin" (Fig. 173).

Water moccasin. — The water moccasin stands next to the copperhead among the poisonous snakes of the United States. It is greenish brown in color with no conspicuous markings and attains a length of four or five feet. Its body is large and thick and its tail is blunt. Its venom is decidedly virulent. It is found from North Carolina to Texas. It is aquatic and lives largely on fishes, tadpoles, frogs, etc.

The rattlesnake. — Although there are several species of rattlesnakes, the common one (Fig. 174) found from the Atlantic coast to the Rocky Mountains will serve as an example. Briefly, the rattle consists of several flattened, horny rings at the end of the body, which are fastened so loosely together that they may be rattled by movements of the tail. The number of rattles do not accurately indicate the age of the snake, as some may be lost and several added during one season. The venom is a straw-colored liquid secreted by two glands situated under the skin on the upper jaw. These glands connect with the long, slender fangs which are hollow. When the mouth is closed, the fangs lie flat against the roof of the mouth; but

when the snake strikes, they are erected and thrown forward. The venom trickles through the hollow fangs and flows directly into the wounds made by them. The fangs are normally shed every six or eight weeks and renewed

FIG. 174. — Rattlesnake (*Crotalus horridus*).

as often. Therefore, the rattlesnake cannot be rendered permanently harmless by the removal of its fangs. Death by the bite of a rattlesnake is by no means sure, but the bite always causes intense pain.

The rattlesnakes,[1] water moccasin, copperhead, and har-

[1] The massasaugas are included among the rattlesnakes.

lequin snake constitute the poisonous snakes of the United States.

By far the greater number of snakes in the United States are harmless. Among these are the small green snakes that live in the grass and are known as grass snakes. The large, dark brown water snake that is so abundant along streams and feeds upon fishes and frogs is a common snake of the eastern United States. It is an unpleasant and ill-tempered but perfectly harmless snake. The pilot snake is one of our largest snakes. It is lustrous black and attains a length of five or six feet. The king snake, corn snake, and spotted adder, all closely related to each other, are rather conspicuous snakes because of their coloring and are fairly common.

Chief characteristics of the snakes.—The bodies are long, cylindrical, and covered with scales. The skin is shed at intervals. The limbs are absent or rudimentary, and the mouth is very dilatable. They progress with a gliding movement by means of scales on the under side of the body. Most snakes lay eggs, but some bring forth their young alive.

Lizards

Like the snakes, there are several species of lizards in the United States, more species being found in the South than in the North, and more in the West and Southwest than in the eastern parts of our country.

Blue-tailed lizard.—One of the lizards common to the United States east of the Rocky Mountains is known as the blue-tailed lizard, and, in some localities, as the "scorpion." Above, it is a dark, glossy green, with five yellowish lines running lengthwise, and the tail is usually of a brilliant blue,

hence its name. Sometimes the tail is a reddish green. Below, the animal is pearly white. Its body is cylindrical and eight or ten inches long. It has four legs, each ending in five toes, and the body is covered with scales. Unlike the snake, the jaws are not dilatable.

Alligator lizard. — This lizard is also known as the "pine lizard." It is six to eight inches long, earthy brown

FIG. 175. — Alligator lizard. In the struggle for existence, part of the tail was broken off.

above, and dirty white beneath, with blue side patches in the male (Fig. 175). Its body is covered with scales, which on the back are large; and when angered, it elevates these scales as a dog does its hair, and rapidly changes its color, thus assuming a very militant aspect. If, by chance, the tail of this animal is pulled off, it will be renewed. The female lays from six to eight eggs in some secluded place in a dry tree trunk, stump, etc.

American chameleon. — This is a small but very beautiful and interesting lizard found in the southern states. Its body

is scarcely three and one half inches long, but its tail may be six inches in length. It has gained the name chameleon from the fact that it can change its color from green to bronze brown, with all the varying intermediate shades. Its body is covered with delicate minute scales and is

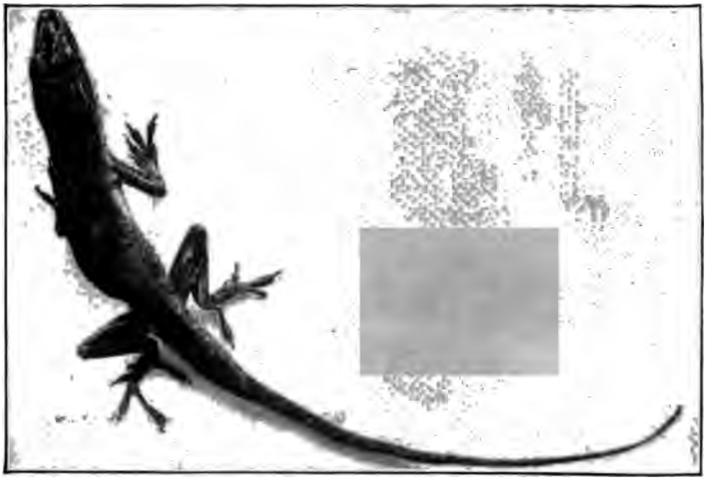

FIG. 176. —American chameleon. Note the toes.

furnished with four nimble legs, which end with very long, slender toes (Fig. 176). Beneath its neck is a fold of bright red skin that makes a very striking appearance when expanded.

Old World chameleons. —The true chameleon, of which so much has been written, is an inhabitant of the Old World. It is found in Africa and Asia along the coasts of the Mediterranean Sea. The head is large and angular, and the body is compressed, and furnished with a long, prehensile tail and with four legs capable of supporting its

weight (Fig. 177). The eyes are large and, to a certain extent, each is independent of the other. The tongue is club-shaped and can be darted out from the mouth to the extent of six or seven inches for the purpose of catching insects on its sticky extremity. There are several layers of different colored pigments in the skin, any one of which may be

FIG. 177. — Old World chameleon.

made to predominate by contracting and masking the others. In this way the animal is able to change its color.

The Phrynosoma. — This reptile is found in the western part of the United States and is known as the "horned toad." The body, barring the tail, somewhat resembles that of a toad, but the spinelike scales that occur on the head, neck, and tail of the animal indicate its relation to the reptiles. The feet and legs are used for running and not for hopping. The horned toads show a remarkable adaptation in coloring to soil on which they live. They can be

kept in captivity easily and thrive on a diet of insects (Fig. 178).

FIG. 178. — Horned toad from Texas.

The Gila monster. — There occurs in the southwestern part of the United States, especially in New Mexico and Arizona, the largest lizard in the United States, the Gila monster. This lizard may attain a length of twenty inches. Its body is deep black with blotches of orange, and covered by hard, rounded tubercles and scales. Recent experiments have shown it to be poisonous. The poison glands are situated in the lower jaw near the anterior end (Fig. 179).

FIG. 179. — Gila monster. Photograph by Shufeldt.

Chief characteristics of the lizards. — They usually possess a cylindrical and more or less elongated body, which in most cases is covered with scales. Four legs are for the most part present, but often are unable to bear the weight of the body and therefore push rather than carry the animal. The mouth, unlike that of the snakes, can be opened only to a normal extent. Finally, the jaws are furnished with teeth, and the food is masticated.

TURTLES AND TORTOISES

These are familiar reptiles to most of us, at least. Some of them live on land and some of them live in the water. The term *turtle* is more usually restricted to the aquatic forms, while the term *tortoise* is applied, if strictly used, to the members of the family Testudinidæ, which are strictly terrestrial in habits and possess club feet, but with distinct toes.

Sea turtles. — We begin with the marine species because these comprise the largest forms. Among the sea turtles occurring along the Atlantic coast is the great leather-back turtle, one of the largest living turtles, which attains a length of six to eight feet and weighs nearly a thousand pounds. Its bony, boxlike body is covered with a thick, leathery skin and the toes are joined together to form paddles for swimming. Another is the hawkbill turtle, which is not much over a third as large as the leather turtle. The bony box in which it is incased is covered with horny scales which furnish the "tortoise shell" of commerce. These scales, or plates, peel off when the shell is properly heated.

A third sea turtle is the green turtle. This turtle has gained considerable notoriety from the fact that it furnishes the basis for that delicious dish, green turtle soup. This reptile occurs in all tropical seas, but in our own country it is found along the Atlantic coast from the Carolinas south, and often weighs as much as eight hundred pounds. It lives on the roots of a sea plant known as eel grass or turtle grass. In the early summer the female turtle crawls on to the sandy shores of islands in the Gulf of Mexico or Caribbean Sea and lays, in a hollow which she scoops out of the sand, from one to two hundred eggs about the size of hen's eggs. When through laying, she covers the eggs with sand and slips into the sea.

Painted turtle. — This turtle is very common in the ponds and streams from Canada to the Gulf of Mexico. During the winter it hibernates, but it comes forth with the first warm days of spring. Its advent is often heralded by shrill piping notes. The eggs, laid in a sand bank, are hatched by the sun. Above, the plates of this turtle's shell are a

dark brown bordered by a band of yellow. Those on the edges are marked with red.

Snapping turtle. — This turtle (Fig. 180) is found in streams and ponds east of the Rocky Mountains, from Canada to Mexico. The shell is too small for the complete retraction of the head and tail, consequently it defends itself with its strong jaws. The snapping turtle is one of our largest inland turtles, often attaining a length of three feet.

Fig. 180. — Snapping turtle.

Soft-shelled turtle. — The common soft-shelled turtle is found in the tributaries of the upper Mississippi and in those of the St. Lawrence. Its toes, like those of the foregoing species, are webbed for swimming because this turtle is distinctly aquatic. The shell is not completely ossified, and, moreover, is covered with a soft skin.

Gopher turtle. — The gopher turtle is strictly terrestrial, its toes are bound up within the clublike foot, and the limbs are fitted for walking. It is common throughout the sandy pine regions of the South. The front feet are flat and wide, very much like those of a mole, and each ends in five strong, flat nails for digging (Fig. 181). When the

head is retracted the front feet and legs are brought around in front and used completely to close the opening in the front of the shell. The hind feet are club-shaped and each

FIG. 181. — Gopher turtle.

ends in four toe nails. They live in burrows dug in the soil to the depth of four or five feet.

Chief characteristics of the turtles. — The bodies are short and stout and incased in a more or less bony box, called the *shell*. The shell consists of two portions, an upper portion, the *carapace* (Fig. 182), and a lower portion, the *plastron*. These are immovably united by the edges, along the sides, but remain open in front for the protrusion of the head and fore legs, and behind, to allow action of the hind legs and afford room for the tail. The turtles have no teeth, but the horny jaws have sharp, chisel-like edges that form a most efficient cutting apparatus. In most cases the head, tail, and legs may be retracted within the shell. In most turtles the shell is very completely ossified and covered with scales. In the soft-shelled turtles, the shell is not so bony but remains soft, while in the leather turtle, the soft

shell is covered with a layer of fatty material which yields considerable oil. The sight of turtles is very keen, for they

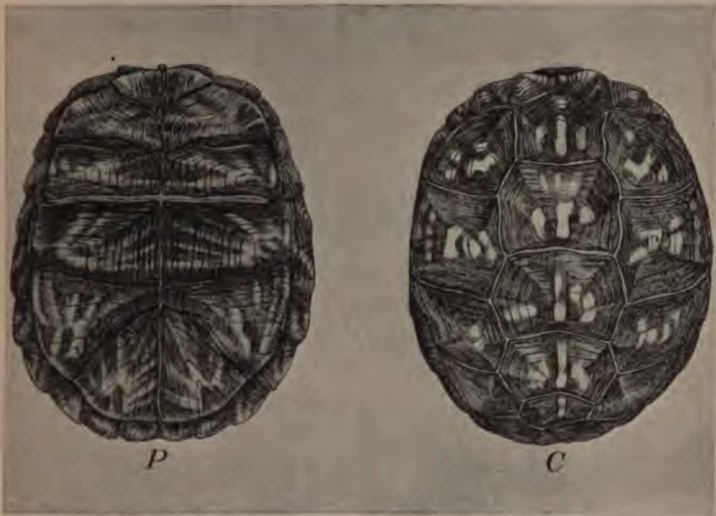

FIG. 182. — Turtle's shell: *P*, lower side or plastron; *C*, upper side, or carapace.

possess well-developed eyes. Unlike snakes, turtles are furnished with legs.

Crocodiles and Alligators

Only one species of crocodile and one of alligator occur in the United States. The crocodiles are rare and are found only in the southern part of Florida. The alligators are fairly abundant at present although gradually disappearing and are found only in the southern states.

Crocodiles. — Crocodiles are found in Florida, West Indies, South America, and Africa, notably along the Nile,

and in Asia. The American crocodile can be distinguished from the alligator by its narrower snout. It sometimes attains the length of twelve feet. Crocodiles are ferocious and kill many large animals which are seized by the snout as they come down to the water to drink.

Alligators. — Like the painted turtle, the alligator spends much of the day lying along a log basking in the sun,

Fig. 183. — Young alligator.

ready to slip into the water at a moment's notice. Alligators are exceedingly active in the water and live upon animals that come to the water to drink and upon fish. They always drag their prey beneath the water and drown it. The passage leading to the lungs is closed by a peculiar arrangement at the base of the tongue, so that no water

can enter the lungs. These animals come to the surface to get air, and the tip of the snout where the nostrils open may often be seen projecting just above the water for this purpose.

In the spring season the male alligators bellow very loudly. The eggs are laid sometimes in a hollow in the sand, and sometimes in a mound built by the reptile. The eggs are deposited in layers, with grass and sticks between. They are left to be hatched by the sun. Alligators seldom attain a length of twelve feet (Fig. 183).

Characteristics of this order. — These reptiles are regarded as the highest of the class, for several reasons. The heart, for example, is divided into four chambers which is much like that of the birds. The brain is more like that of the birds than the brains of other reptiles. The stomach is very birdlike.

The crocodiles and alligators are covered with large, bony scales and the limbs are fitted for crawling and swimming, the toes being partly webbed. The jaws are furnished with many conical teeth implanted in sockets, and the eyes are well developed and furnished with three lids.

Adaptations and habits of the reptiles. — Probably no group of vertebrates offers a more striking example of adaptations to surroundings in the matter of coloring than snakes. There are the small grass snakes that are green in color to resemble the grass in which they live. Those snakes that live in trees are colored to resemble the bark or the leaves. There is a snake living in India that is perfectly harmless, yet so closely resembles the hooded cobra in form, color, and markings that it deceives those well acquainted with both. The neck is dilatable like that of the cobra. There can hardly be a doubt that this is a case of protective resemblance.

Says Packard, "notwithstanding the fact that snakes have no legs, they can creep, glide, grasp, suspend themselves, erect themselves, leap, dart, bound, swim, and dive." All of which shows that they are wonderfully well adapted to their environments.

Many lizards possess feet adapted to climbing trees. The toes are long and end in claws especially well adapted to clinging to the bark of trees. The Old World chameleons have feet especially modified and adapted to clasping branches because they spend their lives in trees. The tongue of this lizard is remarkably well adapted to catching insects.

More remarkable still, are the so-called flying dragons, or dracos of the East Indies. The dracos have a horizontal expansion of skin along each side of the body which is supported by several of the posterior ribs. These animals, from seven to eight inches in length, live in trees and are constantly shooting through the air from tree to tree by means of the side parachutes. Other lizards burrow in the ground and have their feet modified for digging.

In considering the turtles, we find those that live in the sea have paddlelike legs for swimming, while those living partly on land and partly in the water have legs for walking, but the toes are webbed for swimming, while those wholly terrestrial have legs fitted for walking and toes without webs.

The crocodiles and alligators are aquatic animals and possess at least one very remarkable adaptation for such a life. There is at the base of the tongue a transverse fold which, meeting a similar fold on the palate, completely shuts off the mouth from the throat, thus preventing the water entering the windpipe when they drown their prey.

The nostrils also have valves for closing them to keep out the water. The feet of the crocodile are webbed and the tails of both are flattened for swimming.

CLASSIFICATION OF THE REPTILES

Class — Reptilia.
- Order — Squamata.
  - Suborder — Lacertilia.
    - Types of Order.
      - *Cnemidophorus sex lineatus* — Six-lined lizard.
      - *Eumeces quinquelineatus* — Blue-tailed lizard.
      - *Sceloporus undulatus* — Alligator lizard.
      - *Anolis carolinensis* — American chameleon.
      - *Chameleo vulgaris* — Old World chameleon.
      - *Phrynosoma cornutum* — Horned toad.
      - *Heloderma suspectum* — Gila monster.
  - Suborder — Ophidia.
    - Types of Order.
      - *Eutænia sirtalis* — Garter snake.
      - *Python (several species)* — Python.
      - *Naja tripudians* — Hooded cobra.
      - *Agkistrodon contortrix* — Copperhead.
      - *Agkistrodon piscivorus* — Water moccasin.
      - *Crotalus horridus* — Rattlesnake.
- Order — Chelonia.
  - Types of Order.
    - *Sphargis coriacea* — Leather turtle.
    - *Chelone mydas* — Green turtle.
    - *Chelone imbricata* — Hawkbill turtle.
    - *Chelydra serpentina* — Snapping turtle.
    - *Chrysemys picta* — Painted turtle.
    - *Aspidonectes spinifer* — Soft-shelled turtle.
    - *Testudo polyphemus* — Gopher turtle.
- Order — Crocodilia.
  - Types of Order.
    - *Crocodilus acutus floridanus* — Crocodile.
    - *Alligator mississippiensis* — Alligator.

XXII. BIRDS

CHORDATA (*continued*)

Class V. — *Aves* (*avis*, bird)

As a class, the birds are very uniform in their essential characteristics. There is probably not a bird in existence that would not be recognized as such on sight. The birds of the world have been grouped into nineteen different orders, seventeen of which are represented in North America. They are widely distributed and are of very great service to man, although their usefulness is poorly understood and but little appreciated. Notwithstanding the fact that all birds possess feathers, they exhibit a considerable variety of form and habits. Some are flightless and run upon land; some are flightless and live almost entirely in or upon the water; some have very great powers of flight and spend their lives flying over the sea, while others with equally strong wings soar high in the air over land. Some fish for a living, some come forth at night to kill, some scratch for their food, while others live upon seeds and various vegetable products. The study of birds with a field glass and camera, not with a gun, is one of the most interesting and enlightening lines of natural history work.

EXAMPLE OF THE CLASS—THE ENGLISH SPARROW

Origin and distribution. —This sparrow was introduced into America from England about 1850 and for this reason

it is called the English sparrow. It is not, by any means, confined to England on the Eastern continent, for it is really the house sparrow of Europe and Asia. This bird is now widely distributed over the United States and the southern portions of Canada. Throughout its range it is found principally in towns and villages or around farm buildings and along highways. It does not frequent mountainous or forested regions.

External features. — We find the same general arrangement of the body parts as in the lizard; namely, head, neck, trunk, and tail, the latter much shorter than that of the lizard. The limbs also differ markedly from those of the lizard or frog. The limbs of the sparrow may be designated as upper and lower, the former being modified into organs of flight while the latter serve as organs of locomotion on the ground and for perching. Over the whole body is a covering of feathers, the most characteristic feature of all birds. The anterior part of the sparrow's head is prolonged into a bony structure known as the beak. The tail is furnished with long quill feathers.

Plumage. — The body of the sparrow is not so uniformly covered with feathers as it appears to be. In some places the feathers are thin, in fact are entirely absent, while in others they are very numerous and thick; but the thinner areas are covered over by the feathers overlapping each other so that no bare places are to be seen. There are four kinds of feathers on the body of the sparrow: the quill feathers, the contour feathers, the down feathers, and the thread feathers. The long feathers on the tail and wings are the quill feathers. The wing quills aid the sparrow in flying and the tail quills, acting together, serve both as a rudder and as a balancing apparatus when in the act of

FIG. 184. — Feather: *a*, quill; *b*, rachis; *c*, vanes.

perching. All of those feathers that make up the general contour of the body and bear the color pattern are known as the contour feathers. They protect the body from cold, rain, etc. They are efficient non-conductors of heat and retain the heat of the body. Lying beneath and between the contour feathers are many small, soft, loose feathers that are known as the down feathers. They also serve admirably to retain the heat of the body. Finally, scattered over the body, but concealed by the other feathers, are certain hairlike bodies known as the thread feathers. It is these that are left on a fowl after it is picked and that are removed by singeing.

Amidst the feathers above the base of the tail is the oil gland which secretes an oily fluid that is distributed over the feathers with the beak.

Structure of a feather. — A feather consists of two main parts, the quill and the vane (Fig. 184). The quill is a hollow, horny stalk, that extends from the origin of the feather to the vane. The vane is the flat, expanded portion of the feather. It has a longitudinal axis, the *rachis*, which is a continuation of the quill but differs in being solid. Running obliquely to the right and left, on each side from the rachis, are delicate, threadlike structures, called the *barbs*, which are closely held together by other delicate, threadlike structures running out from them, termed *barbules*. The latter are interlocked with one another, thus uniting the barbs and forming a continuous sheet. The feathers grow from small conical projections of the skin, called *papillæ*. In this respect they differ from hairs which grow from deep invaginations of the skin.

Wings. — Each wing consists of three parts: the arm, forearm, and hand (Fig. 185), which correspond with the

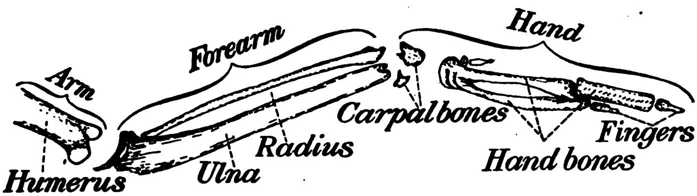

Fig. 185. — Bones of sparrow's wing.

like parts of our own arm. The wings are concave on the inside and fit snugly to the body, really adding to the symmetry and beauty of the bird. When the wing is folded, the arm, forearm, and hand form the letter Z, a position our

arm cannot assume because our hand has not so much freedom of movement at the wrist. The long feathers that grow upon the end portion, or hand of the wing, are called the primaries and those on the forearm the secondaries.

The wings are attached to the dorsal side of the body so that the weight of the latter will be suspended from the point of support when the bird is flying.

Legs and feet. — The legs of the sparrow are slender and short, for they are not much used as organs of locomotion. Sparrows hop rather than walk and long legs are not needed. Like the wings, the legs are attached well toward the dorsal side of the animal so that the weight is *suspended* from the point of support. This is of advantage to an animal that is obliged to reach the ground for all of its food. The hip joints act as pivots on which the body swings between the legs.

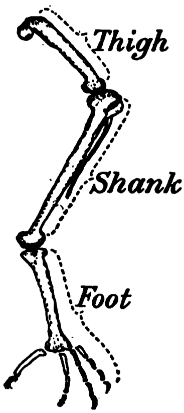

FIG. 186. — Bones of sparrow's leg.

Each leg consists of three parts: thigh, shank, and foot (Fig. 186). The foot is made up of the four toes and the ankle which is the scaly part of the leg not covered by feathers. Each toe is composed of several segments and ends with a claw.

Perching. — The sparrow belongs to the perching birds. Whenever the feet of the sparrow are placed on a support and the body lowered, the toes will automatically close and grasp the perch. A tendon running from the toes passes up the leg in such a way that whenever the leg is bent, the tendon is pulled so strongly that the toes are curved about the support. The closer the body gets to the support, the more firmly will the toes grasp it. Therefore, the sounder

the sparrow sleeps, the more securely it sits upon its perch. In addition to this arrangement, there are muscles by which the bird can voluntarily cling to a support.

The head and neck. — The head is small and light and the neck is long and muscular. Any animal that stands high from the ground must have a long neck with which to reach its food. At the same time the head must be as light as possible to enable such a long neck to support it without fatigue. The anterior part of the head is prolonged into a hard, horny beak, the grasping organ of the sparrow. The beak consists of an upper and a lower mandible, but is not furnished with teeth. No living bird has teeth. The beak is made to withstand the wear of picking food from the hard ground or other surface. Besides, it is used as a weapon of defense.

The alimentary canal. — The gullet leads directly to a large pouch, the crop, in which the hastily procured food is stored for a time. The walls of the crop are provided with bands of muscles which, by their contractions, set up a slow churning movement. Following the crop is the slightly dilated and glandular stomach. Situated just a little beyond and below the stomach is the thick-walled gizzard. The intestine immediately follows, forming, at first, a long loop, the duodenum, and then passing on toward the anal aperture, expands at its terminal part into a wide, saclike portion, the *cloaca*. Situated within the loop forming the duodenum is the pancreas which is directly connected with this part of the intestine. The gall bladder of the overlying liver is also connected with the duodenum (Fig. 187).

The digestive process. — The process of digestion is begun in the crop. Here the food is slowly churned and moistened by the juices given out by the glands of the crop. Passing

on to the stomach the food is further acted on by the digestive juices of this organ. In the gizzard the food is masticated, as it were, and more thoroughly mixed with the digestive juices trickling into the gizzard from the stomach. In the absence of teeth, pebbles are swallowed and retained

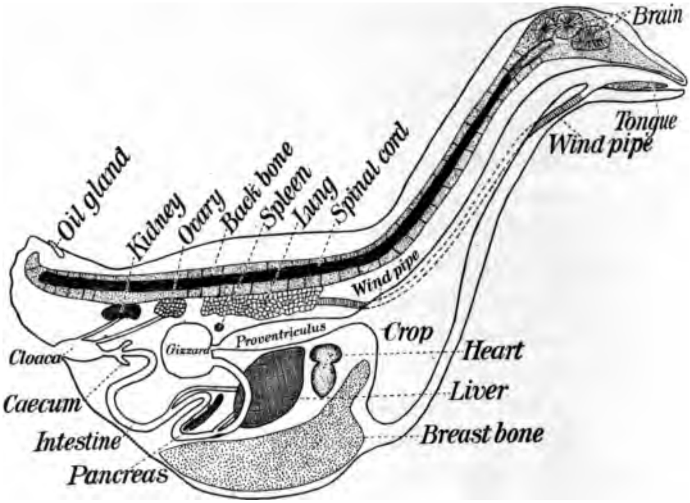

FIG. 187. — Internal structure of a bird.

in the gizzard to aid that organ in reducing the food. In the duodenum the food receives the final digestive ingredients, the bile from the liver and the pancreatic juice.

The circulatory system. — The heart of the sparrow is four chambered and the left side is completely separated from the right side; therefore there is a double circulation, that is, one set of blood vessels carrying impure (venous) blood and another set carrying pure (arterial) blood. Birds are very active animals, and the circulation is much

more rapid in them than in man, and the temperature of the blood is higher than in any other animals.

Respiratory system of the sparrow. — In keeping with the active circulation of the blood, the respiration of the sparrow is also very rapid. The lungs are fastened to the dorsal walls of the body cavity and fit closely between the ribs. Connected with the lungs are certain large air sacs in the abdominal cavity. Moreover, many of the bones of the sparrow are hollow and contain air spaces connected with the lungs.

Excretory system. — The main excretory organs are the kidneys, which are fitted into the spaces between the bones of the back in the posterior part of the body cavity. They are tri-lobed and discharge their excretions into the cloaca with which they are connected by slender ureters.

Nervous system. — The brain is well developed and the anterior part consists of two large, smooth, pear-shaped bodies, the *cerebral hemispheres*, which constitute the *cerebrum*. The *olfactory lobes* project from the anterior ends of these hemispheres. Directly posterior to the cerebrum and on a middle line is the transversely furrowed *cerebellum*. On the ventral side of the brain are the two optic lobes. From the brain the spinal cord runs throughout the length of the backbone, giving off nerves to all parts of the body. The nervous system of a bird is relatively large.

Senses of the sparrow. — The nostrils of the sparrow are at the base of the upper mandible of the beak and open into the mouth. Yet we are not sure that a bird has a very keen sense of smell. On the other hand, we are positive that the sparrow has a well-developed sense of sight. This is true of all birds, especially of eagles and hawks. The eye

has three lids, an under and an upper lid and a third lid that can be drawn over the whole eye, known as the nictitating membrane. The sparrow has no external ear, but the opening to the internal ear may be seen just back of and a little below the eye. It is covered by a tuft of loose feathers. The sense of hearing is keen, and birds depend upon their sense of sight and of hearing to detect their enemies. The sense of touch is distributed all over the body.

Life history of the sparrow. — The sparrow builds its nest in almost any nook or cranny about the cornices of buildings or among the branches of trees. The nest is a simple one made of stems and twigs mixed with hair and grass and lined with feathers. Six to ten eggs are laid at a time and there are five or six broods in a season. Sparrows multiply very rapidly, and were it not for rats, mice, snakes, cats, etc., they would be much more abundant than they are. They are exceedingly hardy birds and crowd out other kinds.

The sparrow's adaptation to flight. — In the first place, the general form of the body is conical, thus offering as little resistance to the air as possible. The covering of feathers give buoyancy to the body and aid greatly in sustaining the weight of the animal in the air. The wings are placed near the dorsal side of the body so that the weight of the animal will hang suspended from the point of support and lessen the liability of being overturned in the air. The breastbone is furnished with a ridge, or keel, and the sides are long and sloping to afford space for the attachment of the powerful muscles that move the wings. Moreover, the large feathers on the wings and the manner in which they are arranged increase the surface of these organs of flight and enable them to present additional re-

sistance to the air. The bones are filled with air spaces and there are large air sacs in the abdomen connected with the lungs, all of which tend to lessen the specific gravity of the body.

Food and economic importance. — The food eaten by the English sparrow and the bearing this has upon its economic importance has been given considerable attention by the United States Department of Agriculture. In all, 632 stomachs of these birds, of which 50 were nestlings, have been examined and the contents of each accurately determined. Figure 188 gives a graphic representation of the result of this investigation. Two per cent of the year's food consists of animal matter, chiefly insects; 24 per cent of grass and weed seeds, and 74 per cent of grain. The fact that grain was found to constitute nearly three fourths of the food of the adult sparrows has brought merited condemnation upon this small but abundant bird. Moreover, the results of the examination of the 50 stomachs of nestlings bring additional reproach upon this sparrow. The food of the nestlings of our native sparrows, so far as we know, consists exclusively of animal food, mainly insects. In contrast with this it was found that 33 per cent of the food of the aforementioned 50 nestlings was composed of grain. In justice, however, it must be added that 65 per cent of the food consisted of insects, chiefly grasshoppers. Taking this record as a whole, we must class the English sparrow as decidedly injurious to agri-

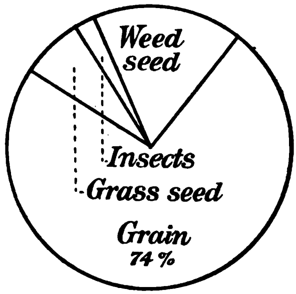

FIG. 188. — Diagram showing proportions of food of an English sparrow.

cultural interests. This bird does eat some weed seeds, especially in the public parks of cities and towns; but here again, the good it does is largely offset by the injury it works to buildings and statues, and we are driven to the conclusion that the bird is a serious pest which ought to be exterminated.

XXIII. BIRDS (*continued*)

CHORDATA (*continued*)

Ostriches and cassowaries. — The ostriches and cassowaries are wholly unable to fly and are, therefore, known as the flightless land birds. At the same time, they are the lowest members of the class. The breastbones of these large birds differ decidedly from that of the sparrow, for they are flat, or unkeeled. This is in keeping with their small, functionless wings. The majority of these birds are large and possess strong legs with which they can kick viciously and effectively and run swiftly.

FIG. 189. — Cassowary.

The true ostriches live on the sandy plains of South Africa and Arabia. Unlike the sparrow, the feathers in the tail and wings of the ostriches are long and plumelike and furnish the feathers so commonly used for ornament. The ostrich is the largest living bird, measuring from six to seven feet in height. It has long, strong legs with two-toed feet and can run faster than a horse. Its wings are rudimentary and it does not

fly. The male has black feathers on the body with white plumes on the wings and tail, while the female is of a sober, brownish gray. The eggs, which are five or six inches in diameter the long way, are laid by the female in a hole scraped out in the sand by the male. The male does most of the incubating.

Ostriches are now reared on farms in Africa, South America, California, and Arizona.

The so-called South American ostrich is not a true ostrich but belongs to a different genus from the one above. Its feathers are not so valuable, being used for rugs, dusters, etc.

The cassowaries are large birds that, like the ostriches, have flat breastbones and rudimentary wings. They live in the dense forests of Australia, New Guinea, and other islands adjacent (Fig. 189).

Loons, auks, and penguins. — These are all adapted to an aquatic life. They are expert divers and swimmers, and some of them are strong flyers. They are not at ease on land, because the legs are set far back, which gives them an awkward appearance, and ill adapts them to walking, but enables them to develop great propelling power in water. The feet are webbed.

The common loon, often called the great northern diver, is migratory, ranging south to the Gulf in winter, but going north in spring, in pairs, to rear the young around some body of fresh water. The eggs are usually laid in rude nests among the reeds, close to the water. Loons have a peculiar loud call, hence the expression, "yelling like a loon."

The great auk was the only bird in North America incapable of flight. It resembled the penguins in this respect, and nested on the islands in the North Atlantic. It is now extinct, having become so within the last generation.

Penguins are preëminently aquatic birds and are found on the islands in the Antarctic Sea. The wings are small and adapted to swimming (Fig. 190), for they are used only as paddles. The legs are short and, on land, form very clumsy organs for walking, but in the water serve as rudders. The penguins live in great flocks; and, in the egg-laying season, it is almost impossible to walk through the rookeries without stepping on the young birds or eggs, so closely are they crowded together.

FIG. 190. — Penguin.

Albatross and petrel. — These are representatives of a group of water birds that possess long, pointed wings and are strong, swift flyers. They are not water birds in the sense of swimming and diving, but rather in the sense of living near the water, flying over it much of their time, and eating fish and other animals found in water.

The wandering albatross is a water bird of a very different type from the penguin. It is the largest water bird living and has the greatest wing expanse of any bird on the sea. The wings vary in different individuals from ten to twelve feet from tip to tip. It is probably the greatest flyer, in regard to distance and time spent on the wing, of any bird known. For days and days this bird will follow a vessel at

sea, sometimes circling above it, sometimes just topping the furious waves, and sometimes skimming the calm sea, apparently ever on the wing. Some declare that it never rests at all in these long flights, but its feet are webbed, which is a pretty strong indication that it rests on the water at some time.

There is a small, web-footed, sea-loving bird that is known to the sailors as "mother Cary's chicken." This is the little stormy petrel. It literally lives upon the sea, spending nearly all of its time in flying and skimming over the water just low enough to paddle the surface with the feet and assist the wings.

The gulls and terns. — The gulls are also strong and graceful flyers, but unlike the albatross and petrel they frequent inland bodies of fresh water, especially the Great Lakes and larger rivers as well as all the salt water bays and inlets of North America. The herring gull, which is our most common gull, wings its way far out to sea and also ranges far inland around the Great Lakes, the lakes and ponds of Michigan, Minnesota, and Iowa and the large rivers of the United States.

The common tern, or "sea swallow," breeds in a few places along the Atlantic coast between New Jersey and Nova Scotia. It is much smaller than the herring gull and not so graceful, especially when it is on the ground.

The cormorant and pelican. — These are water birds, and strong flyers like the petrels and gulls. The feet are webbed, the web even including the hind toe which is free in other birds.

The cormorants are rapacious and greedy. They live and nest in great flocks, mostly along the rocky shores near the sea. Some of them, at least in former times,

nested inland. Their nests are loosely built of coarse reeds, seaweed, sticks, etc. They live largely on fish, and are of an iridescent, greenish black color, with green eyes a color not often seen in birds. They dive and swim with ease.

The white pelican that occurs over much of the United States is a large white bird with long wings and webbed feet. It is remarkable for the large pouch beneath its bill, which is used for dipping up fish. One author says that "several thousand of them are permanent residents of Great Salt Lake, Utah, breeding on the islands twenty miles out in the lake." They make their nests on the ground and lay two to four eggs in it.

Geese, ducks, etc. —The geese, ducks, and swans belông in the same group and are therefore closely related. These water birds have three toes of the feet webbed and their bills are rather broad and are furnished along each cutting edge with a series of toothlike processes. It is a large order and once each year its members come up from the tropics and subtropics to nest and rear their young. Some of them stop in the temperate zone, but many of them go beyond the Arctic Circle among the lands of snow and ice.

In the autumn, after the young have waxed strong of muscle and wing, they retrace their long flight over land and sea to warmer regions to spend the winter.

Of the ducks the mallard is the largest and handsomest. Besides, it is the parent of nearly all of our varieties of domestic ducks. It abounds in many parts of the United States, nesting in the tall grasses around the margins of ponds, beside small streams, etc.

The canvasback duck has fallen a victim to the insatiable appetite of the epicure and is fast disappearing from North America. The eider duck occurs along the north

Atlantic coasts of Europe and America. The nests are lined with the soft down plucked by the female from her breast. This down, gathered from the nests, furnishes the eider down of commerce.

The Canada goose is the common wild goose of America. It migrates in the autumn to the South in Y-shaped flocks, and returns North the following spring. It breeds in the northern United States and Canada. The nests, made of grass and sticks and lined with down and feathers, are usually placed on the ground. In most cases wild geese remain around lakes or rivers.

Cranes, rails, etc. — The cranes are large birds with long legs and long necks. They frequent marshy places, ponds, rivers, and small streams. The whooping crane is white, with some black on each wing, and stands three to four feet high. The sandhill crane is common in the Mississippi Valley. The rails are smaller birds, with shorter necks and legs, and hardly any tail. Their legs are strong, and they depend on running, to a large extent, for safety. The Carolina crake is a small, slate-colored bird, much esteemed for food.

Snipe and woodcock. — These are both highly prized game birds, with, perhaps, the woodcock higher in favor. Both of them have long, straight bills, with which they probe into the soft mud about the margins of ponds and streams in search of earthworms. The woodcock has a relatively large body, with short legs and tail, feeds mostly at night or in the shelter of undergrowth and is consequently difficult to kill. The snipe (Wilson's snipe) usually feeds in more open ground and when it takes flight, utters a shrill cry.

Birds of prey. — The birds of prey include the eagles,

hawks, owls, and buzzards. This group of birds is not a large one, but among its members are found both friends and enemies of man. The owls have been much maligned for their depredations upon poultry, but, as a whole, owls are among the most beneficial of all birds. There are eighteen species of owls in North America north of Mexico. The more familiar ones are the barn owl, the best feathered friend the farmer has, for it lives almost entirely on rats and mice; the great horned owl, which it must be confessed destroys much poultry, yet, at the same time, kills many mice; the screech owl (Fig. 191), and the long-eared owl. The burrowing owl is found on the plains of the West from North Dakota to southern California. This owl burrows readily into loose soil.

FIG. 191. — Screech owl.

The eagles (Fig. 192) are majestic birds of large size and furnish an inspiring spectacle in their lofty flights above the crags and mountain tops. The feet of the eagles are very strong and every toe is furnished with a strong, curved talon for grasping and holding the prey. The bill is short, stout, curved at the tip, and has sharp cutting edges. It is admirably adapted to cutting and tearing flesh. While

FIG. 192. — Bald eagle.

eagles are on the wing, at a great height, they often locate their prey, and dash downward after it. The eyes are provided with a series of bony rings in front, which, acting like a telescope, enable them to see near and distant objects.

Hawks are very similar to the eagles in all the points mentioned above and are closely related to them. See Fig. 193.

The carrion crow and turkey buzzard that are so common in the South are birds of prey also and belong to the same order as the eagles and hawks. The buzzards live on dead animals and the claws are clumsy and not especially fitted for grasping.

Quails, partridges, etc. — In this group of birds are found most of our domestic fowls; as hens, turkeys, peacocks, etc.

The quail, or bobwhite, is perhaps the most noted game bird

FIG. 193. — Head of a hawk.

in this group. It ranges from Kansas, Indian Territory, and Texas to the Atlantic coast, and from the Gulf to Canada. They are usually found in flocks called "coveys." Their favorite nesting places are in the corners of fences, among the weeds in cultivated fields, and at the bases of stumps on the ground. The quail lays from twelve to twenty-five eggs. The ruffed grouse, or partridge, is common in the eastern United States. The male, standing on a log in the mating season, makes a well-known drumming sound by beating his body with his wings. Other birds belonging to this group are the ptarmigans, pheasants, prairie hens, etc. The bills of the members of this group are short and stout, and the feet, in most of them, are fitted for scratching.

Doves and pigeons. — The doves and pigeons are rapid flyers. The toes, which are fitted for grasping and perching, are usually on the same level. The base of the bill is covered by a soft membrane beneath which the nostrils open. They frequent cultivated ground in flocks in search of grains and seeds. The mourning or turtle dove is found all over temperate North America.

Woodpeckers. — They have strong, sharp bills for drilling holes in wood. The tail feathers, which are stiff and sharp, aid in supporting the body of the bird when perched on the upright trunk of a tree. The feet have two toes pointing backward and two forward, an arrangement that also aids the bird in perching on a perpendicular surface. The red-headed woodpecker is abundant in the central United States. It excavates holes in trees, telegraph poles, etc., in which to build its nests. There are several species of woodpeckers in the United States. Some of them do much good by destroying the larvæ of insects that bore

into trees. These birds drill holes into the trees, impale the larvæ on the long barbed tongues, draw them out, and devour them. The yellow-bellied sapsucker is a woodpecker that is very fond of the sap of forest and fruit trees. And, although it devours many insects, it undoubtedly damages trees by boring rows of holes through the soft bark to obtain the sap.

FIG. 194. — Nest of a ruby-throated humming bird.

Whippoorwills, swifts, and humming birds. — This group of birds contains forms that differ so much from each other in appearances that their close relationship would scarcely be recognized. Their wings are long and pointed and, in general, they are swift flyers. With the exception of the humming birds, they live upon insects caught while the birds are in full flight. The whippoorwill is common in the eastern United States and is known by its peculiar call. In the daytime it remains silent and hidden in dark, deep recesses of the woods, coming forth only at night to chase insects.

The night hawk, or bull bat, is thought by some to be the same as the whippoorwill. It is a different species from

FIG. 195.—Chimney swift.

the whippoorwill, however. The night hawks are seen sailing and swooping through the air at dusk on summer evenings, in pursuit of insects. Strange to say, they make

FIG. 196.—Nest of a chimney swift.

hardly any nest, even depositing their eggs, at times, on bare rocks or on the roofs of houses, in cities.

The humming birds are well known for their small size, long, slender bills, bright metallic colors, and the humming noise made by the rapid vibrations of their wings as they poise over a flower in search of nectar. Figure 194 shows the nest of the ruby-throated humming bird in the branches of an apple tree.

FIG. 197. — Carolina parrot.

The chimney swifts (Fig. 195) are seen in flocks passing down a chimney at nightfall. Here they build their nests of small branches glued to the sides of the chimney (Fig. 196).

Parrots. — The parrots are mainly inhabitants of the tropical parts of the world, especially South America and Australia. The bill is short and stout and the upper half extends beyond and curves over the lower half. The majority have a brilliant plumage, but some of them are dressed in sober hues. The tongue is large and soft and capable of very free movement. They are, by nature, great

mimics of the voices of other animals. The parrots vary in size, from the love bird, about the size of a sparrow, to the macaws, which often measure three feet from tip of bill to tip of tail. The only parrot found in the United States is the Carolina parrakeet. Formerly this parrot was found as far north as the Great Lakes, but now it is confined to Florida. It is very fond of cultivated grains and this has been one cause of its extermination (Fig. 197).

The toes of parrots, like those of woodpeckers and cuckoos, are in pairs. One pair points backward and one pair forward.

Perching birds. — This group of birds contains over six thousand species, more than all the others combined. Nearly all the familiar birds belong to the perchers. The crows, jays, orioles, robins, bobolinks, sparrows, mocking birds, thrushes, etc., are familiar examples. They are the most highly developed of all the birds, and stand at the head in complexity of organization. The feet of the perchers differ from those of the parrots in having one toe pointing backwards and three toes extending forward, thus enabling them to grasp the object on which they are resting. Many of them are very sweet singers. The mocking bird is considered first in the range and variety of its notes. To the writer, however, the song of no bird will ever awaken so much joy or will linger so long in the memory as the notes of the Wilson's thrush heard lightly rolling and lingering through a wooded glen on a summer eve at twilight. In the mammals, the vocal cords by which sound is produced are situated at the upper end of the windpipe in the larynx. In the singing birds a structure known as the "syrinx," or "lower larynx," is situated at the lower end of the windpipe, next to the lungs. It is here that the sounds are supposed to be produced.

Chief characteristics of the birds. — They are all covered with feathers. The queer "kiwi," or Apteryx, of New Zealand, possesses only hairlike feathers. No living birds possess teeth, but the jaws are modified into a beak incased in a horny covering. The heart is four chambered, and there is a consequent double circulation, — that is, one set of vessels carrying impure (venous) blood, and another set carrying pure (arterial) blood, which is like the circulation in man. The front pair of limbs is modified into organs of flight, which in some are nevertheless useless as such. The temperature of the body is higher than in any other animals. Therefore, for the first time we meet with warm-blooded animals. The bones of many birds are hollow and filled with air. Moreover, there are often air sacs in the body for the purpose of increasing the buoyancy of the animal.

Molting of birds. — A feather does not continue, like a hair, to grow indefinitely; but after once attaining its growth, it remains unchanged until shed, when a new feather grows in its place. Generally speaking, birds shed all their feathers, or molt, once a year, after the breeding season is over. Some birds pass through two molts a year, one in the autumn and another in the spring. The feathers following the autumnal molt may be of one color, while those following the spring molt may be of another. Hence such birds possess a certain color in winter and another in summer, or, as we say, have seasonal colors.

Incubation of birds. — All birds are developed from eggs laid by the female parent, usually in a nest of her own building. The time necessary for the incubation of the eggs varies with different birds. For the majority of birds the eggs are incubated from ten to thirty days, but an ostrich egg requires nearly fifty days of incubation. Some

birds, for example the English sparrow, rear several broods of young a year, but most species have one or two. In some species the male aids in building the nest and takes his turn at sitting on the eggs, while in other species the female does practically all of the work of rearing the young.

Nesting habits. — In building homes in which to deposit eggs and rear the young, birds differ greatly. Perhaps the

FIG. 198. — Nest of a mocking bird.

least careful birds in these matters are the auks. Some of these birds drop their eggs on the bare ground or among the loose stones and rocks with no attempt at making any nest whatever. The majority of birds, however, take great care in building their nests and concealing them from marauders. The Old World cuckoo and the cowbirds

lay their eggs in other birds' nests, and allow the young to be fed and reared by foster parents.

A kind of swift, found in the Polynesian Islands, builds its nests in caves, and constructs them of a mucous secretion which hardens into a tough gelatinous substance. These so-called "edible nests" are used as food by the Chinese.

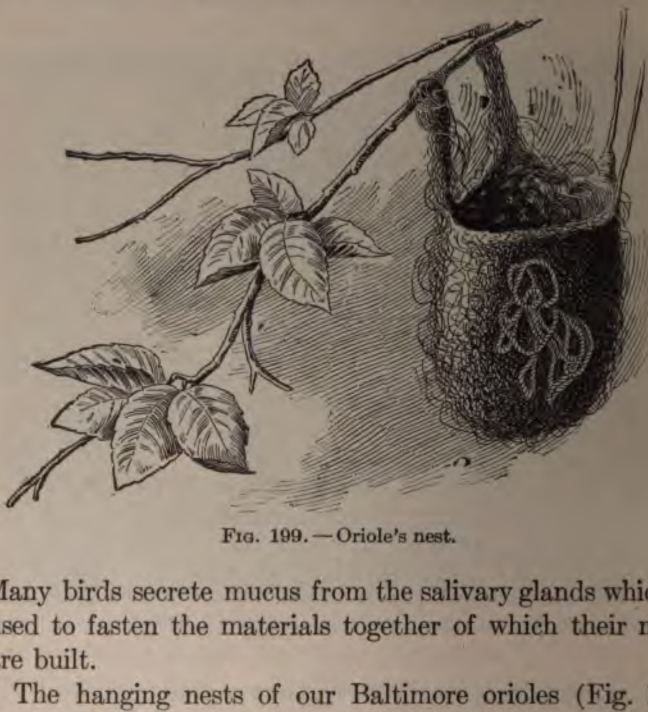

FIG. 199. — Oriole's nest.

Many birds secrete mucus from the salivary glands which is used to fasten the materials together of which their nests are built.

The hanging nests of our Baltimore orioles (Fig. 199) and of the japim of South America are objects of very great interest. The social weaver birds of South Africa build domelike structures out of straw beneath which may be twenty or thirty individual nests. The female hornbill of Africa, Asia, and Australia enters a hollow tree to build

her nest. The entrance to the nest is then sealed up with mud by the male with the exception of a small hole through which the female presents her bill to be fed by her faithful consort. Finally, those wonderful little tailor birds of India select two or three leaves near each other and actually

FIG. 200. — Nest of a blackbird.

stitch the edges together, thus forming a neat receptacle in which to build their nest.

But we do not need to travel to foreign countries to find interesting birds and nests. The habits and nest building of our own birds are always a source of wonderful interest and pleasure to those who study them. Figure 200 shows the nest of a blackbird.

Migrations of birds. — A great majority of the birds that spend the summer in the colder portions of the earth go

southward as winter comes on. Most of the birds from the central and northern United States go to Mexico and Central America in the autumn, to remain during the winter, returning again in the spring. The extent of the migrations of different birds varies greatly. Some go to Alaska or the region of Hudson Bay to rear their young, returning in autumn to Mexico and the West Indies. Others go no farther than the Great Lakes, while the birds of the Rocky Mountain region and Pacific coast migrate very little or none at all.

It is probable that the original cause of these migrations was a change in climate whereby there came about a scarcity of food. The birds were thus forced to journey to other regions in search of something to sustain life. The wandering, thus induced by force, has now been regularly practiced by so many generations that it has become a fixed habit, and probably these birds migrate now from instinct.

In general, it may be said that the migratory birds go in spring to the region of their birth by a definite route. In fact, the routes of some birds have been carefully mapped out. The return in autumn is slower and the route is less definite.

Adaptations to environments and mode of living. — In our discussions of birds many of the adaptations to their mode of living have been brought out, and many others are obvious, hence we only recapitulate them here.

Of course, they are preëminently fitted for an aërial life. The fore limbs are modified into most ideal organs for flight. The breastbone in those birds that fly is of such a shape that it affords the most surface for the attachment of the great muscles that move the wings. The bones of many birds

are hollow, to give strength and lightness. Moreover, the hollow spaces are often connected by tubes with the respiratory organs, by which means they may be filled with air, and the buoyancy thus increased. The wings are attached at the very highest part of the thorax so that the weight of the body is placed below the wings, when outstretched.

Note the penguins, in which the wings have been modified into organs of locomotion in the water, while the ostrich, which lives on land and has no functional wings, is furnished with long, strong legs for running.

The eagles and hawks have eyes and feet wonderfully adapted to their mode of living. The owls also possess eyes adapted to hunting in the night time, hence are able to avoid much competition in obtaining their food.

We can hardly study the habits and structure of any bird without finding interesting adaptive modifications to its environment and mode of living. This phase of the subject is a most entrancing and fruitful study.

The extermination, protection, and economic value of birds. —The rapidity with which the birds are being exterminated is appalling to those who understand and appreciate their value to mankind. One of the most striking instances of the tremendous decrease in the number of birds is shown in the case of the wild, or passenger pigeon. Alexander Wilson saw a flock of pigeons in Kentucky in 1808, that he estimated to contain 2,230,272,000 individuals. Great flocks of these pigeons continued common up to 1840, but now, not only the flocks but the individuals are becoming comparatively rare, especially in the northern United States. Birds are being lessened by hundreds by the fad for egg collecting, confined chiefly to boys. They are being

shamelessly killed by thousands to supply the demands of milliners. Birds are being destroyed by thousands in every state for food. Gun clubs, hunting contests, shooting boys, and cheap firearms are all enemies of birds.

It is small wonder that the cankerworm, the palmer worm, the army worm, the curculios, the codling moth, the locusts and other insects are destroying three hundred million dollars' worth of farm and garden crops every year. It is a wonder that they do not destroy more. If this brutal, thoughtless, and indiscriminate warfare against the birds goes on much longer, we shall be wholly at the mercy of insect pests.

Birds have both an æsthetic and an economic value. They are our best friends and our most cheerful companions. They always welcome us with a song. "When your ears are attuned to the music of birds, your world will be transformed. Birds' songs are the most eloquent of nature's voices; the gay carol of the grosbeak in the morning, the dreamy midday call of the pewee, the vesper hymn of the thrush, the clanging of geese in springtime, the farewell of the bluebird in the fall — how clearly each one expresses the sentiment of the hour or season."

But since the æsthetic side of bird life is not always appreciated, let us consider the economic value of these animals which depends upon their usefulness as destroyers of injurious insects, rodents, and the seeds of noxious weeds. In the air swifts are pursuing insects all day long and at night the whippoorwills and night hawks take up the quest. Flycatchers lie in wait for their prey and the light, active warblers skillfully pick insects from the leaves and blossoms of plants. The woodpeckers, nuthatches, and creepers explore the trunks of trees for hiding caterpillars and

grubs. The thrushes, sparrows, and other birds that live upon the ground devour myriads of insect foes.

Let us consider some individual examples of the contents of birds' stomachs as a proof of their value as destroyers of insects, rodents, and the seeds of weeds. The stomach of one night hawk contained the remains of 38 grasshoppers, another 22, and still another 19. Nearly three fourths of the food of the meadow lark is composed of insects and over 12 per cent consists of weed seeds. The stomach of one quail, or bobwhite, contained 101 potato beetles. Dr. A. K. Fisher examined 200 food pellets which had accumulated from two barn owls that roosted in a tower of a building in Washington and found 225 skulls of meadow mice, 179 of house mice, 20 of rats, 2 of pine mice, 6 of jumping mice, 20 of shrews, 1 of the star-nosed mole, and 1 of the vesper sparrow. The stomach of one mourning dove contained 7500 seeds of the yellow wood sorrel, while another contained 6400 seeds of barn grass. It is useless to multiply examples. If it were not for birds, the earth would be almost uninhabitable.

CLASSIFICATION OF THE BIRDS

- ***Class*** — Aves.
  - *Division A* — Ratitæ.
    - Order — Megistanes.
      - Types of Order.
        - *Casuarius casuarius* — Cassowary.
        - *Apteryx australis* — Apteryx.
    - Order — Rheæ.
      - Type of Order.
        - *Rhea rhea* — South American ostrich.
    - Order — Struthiones.
      - Type of Order.
        - *Struthio camelus* — Ostrich.

Division B — Carinatæ.

Order — Impennes.

Type of Order.

Eudyptes antipodun — Penguin.

Order — Pygopodes.

Types of Order.

Gavia imber — Loon.

Podilymbus podiceps — Pied-bill grebe.

Plautus impennis — Great auk.

Order — Longipennes.

Types of Order.

Larus argentatus — Herring gull.

Sterna hirundo — Common tern.

Order — Tubinares.

Types of Order.

Diomedea exulans — Albatross.

Procellaria pelagica — Stormy petrel.

Order — Steganopodes.

Types of Order.

Phalacrocorax (*several species*) — Cormorants.

Pelecanus erythrorhynchus — White pelican.

Pelecanus fuscus — Brown pelican.

Pelecanus californicus — California brown pelican.

Order — Anseres.

Types of Order.

Anas boschas — Mallard duck.

Aythya vallisneria — Canvasback duck.

Somateria mollissima borealis — Eider duck.

Branta canadensis — Canada goose.

Order — Paludicolæ.

Types of Order.

Grus americana — Whooping crane.

Grus mexicana — Sandhill crane.

Porzana carolina — Carolina crake.

Order — Simicolæ.

Type of Order.

Gallinago delicata — Wilson's snipe.

Order — Raptores.

Types of Order.

Haliæetus leucocephalus — Bald eagle.

Catharista urubu — Carrion crow.

Cathartes aura — Turkey buzzard.

Strix pratincola — Barn owl.

Order — Gallinæ.

Types of Order.

Colinus virginianus — Bobwhite or quail.

Bonasa umbellus — Partridge or ruffed grouse.

Order — Columbæ.

Type of Order.

Zenaidura macroura — Turtledove.

Order — Pici.

Types of Order.

Melanerpes erythrocephalus — Red-headed woodpecker.

Bucerus bicornus — Hornbill.

Order — Macrochires.

Types of Order.

Antrostomus vociferus — Whippoorwill.

Chordeiles virginianus — Bull bat.

Chætura pelagica — Chimney swift.

Callocalia fuciphaga — Swiftlet.

Trochilus colubris — Ruby-throated humming bird.

Order — Psittaci.

Type of Order.

Conurus carolinensis — Carolina parrot.

Order — Passeres.

Types of Order.

Corvus americanus — Crow.

Cyanocitta cristata — Jay.

Icterus galbula — Baltimore oriole.

Dolichonyx oryzivorus — Bobolink.

Passer domesticus — Sparrow.

Mimus polyglottos — Mocking bird.

Sutoria sutoria — Tailor bird.

Merula migratoria — Robin.

Hylocichla fuscescens — Wilson's thrush.

XXIV. MAMMALS

CHORDATA (*continued*)

Class VI. — Mammalia (animals with milk glands)

THE mammals constitute the highest group of the animal kingdom. The class, Mammalia, includes animals of various forms and habits many of which are well known and are of very great service to man. Most of our domestic animals belong to this class.

AN EXAMPLE OF THE CLASS—THE GRAY RABBIT, OR "COTTONTAIL"

External features. — The body of the rabbit presents four regions — head, neck, trunk, and tail, the latter being very short. The whole surface of the body, even the soles of the feet and the inside of the cheeks, is covered with soft hair, an epidermal structure characteristic of mammals. The rabbit has four legs, the hinder pair being much larger and longer than the front ones. Two long external ears and two prominent eyes are present on the head (Fig. 201).

The covering of hair. — A hair is an epidermal outgrowth and arises from a deep cavity, or invagination of the skin. There are three kinds of hair on the rabbit.

The short, soft, kinky hairs that form the greater part of the covering and constitute what we call the fur.

The long, straight, black-tipped hairs that protrude through the fur.

And the long, stiff, bristlelike hairs on the sides of the upper lip and around the eyes. These last are tactile hairs and are situated deep in the skin in intimate connection with nerves.

Eyes. — The eyes are set wide apart and the sense of sight is very keen. Each eye has two movable, opaque lids and an imperfect, vestigial nictitating membrane.

FIG. 201. — Gray rabbit.

Ears and nostrils. — The external ears of the rabbit are very long and large and can be turned in different directions to catch the sound. The inner ear is well developed and the sense of hearing is acute. This animal depends largely upon its sense of hearing to detect the presence of enemies. When hiding from danger in its form, its ears lie flat along the body. At other times the rabbit rises up to its full height, pricks up its ears, and listens.

The nostrils are longitudinal slits at the end of the nose.

Evidently the rabbit's sense of smell is well developed for we often see it moving the end of the nose and upper lip as though in the act of sniffing.

Mouth and teeth. — The mouth is bounded by soft lips and each jaw is furnished with teeth of two sorts, the *incisors* and *molars*. There are two pairs of long, curved incisors in the front of the mouth, one pair on the lower jaw and one pair on the upper. These have sharp, chisel-like edges which meet together and form a very efficient gnawing apparatus. Just behind the large pair of incisors on the upper jaw is a second pair of small, scarcely noticeable incisors. The front surfaces of the incisors are covered with a very hard enamel, while the remaining portion of these teeth are of a softer material. Thus it happens that in gnawing the softer back portions are worn away leaving a sharp cutting edge of enamel in front. Moreover, these teeth grow as fast from their roots as they are worn off by gnawing. This is also true of the teeth of rats, mice, and other gnawers. The upper lip of the rabbit is split in the middle so as to expose the incisors and facilitate the work of gnawing.

Back of the incisors there is a space on the jaws along which no teeth are found. In a dog's mouth, the canine teeth occupy some of this space. Finally, far back in the rabbit's mouth are the molars, or grinding teeth, six pairs above and five pairs below. The upper and lower molars meet by flat, corrugated surfaces. The lower jaw has a sliding, forward and backward movement, while chewing, thus grinding the food between the sliding surfaces of the two opposing molars.

The food. — The rabbit is a vegetarian pure and simple. It lives upon clovers, grasses, buds and bark of trees, etc.

The tongue. — The tongue of the rabbit is thick and muscular and attached to the posterior part of the mouth. It is flattened and tapered toward the front. The soft part of the tongue and certain areas on the thick part are furnished with taste buds. It is believed that the sense of taste is fairly well developed.

The legs of the rabbit. — The fore and hind limbs, which are the organs of locomotion, differ considerably in size and strength. The hind legs are much longer than the front ones and are more muscular. The front legs are divided into upper arm, forearm, and hand. The upper arm is almost hidden by the skin so closely is it applied to the side of the body. The hand has five digits, each ending in a horny claw. The hind legs are divided into thigh, shank, and foot, the latter having only four digits.

Method of locomotion. — When quietly searching for food, the rabbit hops slowly about from place to place. When

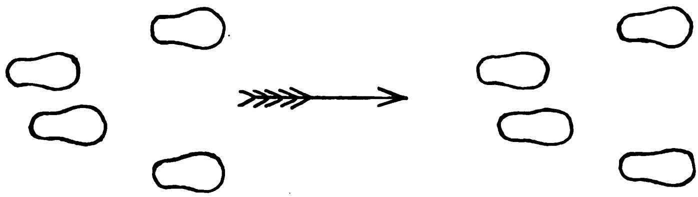

FIG. 202. — Diagram to illustrate the tracks made by a rabbit running.

frightened, it runs swiftly by long, powerful leaps performed with the strong hind legs. In leaping, the flexible body is bent nearly double, the long, hind legs are spread apart, and the hind feet are put down last, ahead of the front ones and on the outside of the latter. The tracks made by a running rabbit are represented in Figure 202. The two tracks close together are made by the front feet, while the

two far apart and in front of the former are made by the hind feet.

The digestive system of the rabbit. — The digestion of the food begins in the mouth where it receives the saliva from four pairs of salivary glands. The food then passes down the long gullet into the large stomach, at the lower end of which is a valve, the *pylorus*, which prevents food from leaving the stomach before it has been properly acted upon by

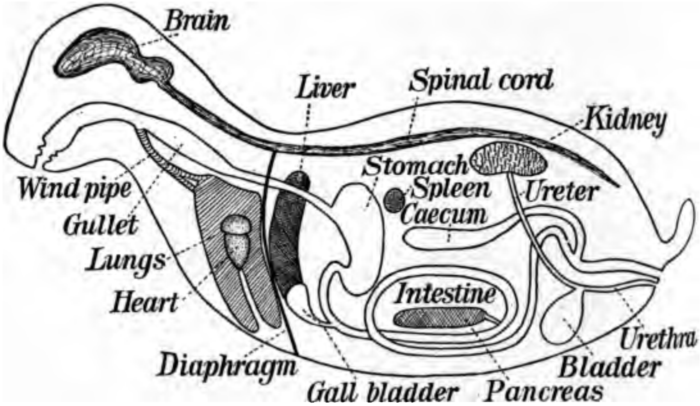

Fig. 203. — Internal structure of a rabbit.

the digestive juices. Following the stomach is the small intestine, the first part of which is called the *duodenum*. The ducts from the gall bladder of the liver and from the pancreas enter the duodenum. The large intestine completes the alimentary canal. At the junction of the small and large intestines is a large, long, blind sac, or pouch, the *cæcum* (Fig. 203).

The body cavity of the rabbit. — The body cavity of the rabbit is divided by a partly muscular and partly tendinous

partition, the *diaphragm,* into two complete cavities, the *thorax* and *abdomen.* In this respect the mammalia differ from all other living vertebrates. Usually the diaphragm lies transversely to the long axis of the body. In the rabbit, then, it lies vertically and in man it lies horizontally.

The thorax, which is the anterior cavity, is bounded by the ribs and contains the lungs and heart. The abdomen is bounded by soft muscular walls and contains the liver, stomach, intestines, reproductive and excretory organs.

Respiration of the rabbit. — On the floor of the pharynx, posterior to the tongue, is an opening, the *glottis,* that leads into the windpipe. The glottis is closed by a lidlike organ, the *epiglottis,* which prevents the food from falling into the windpipe. The larynx, or voice box, is situated at the upper end of the windpipe which divides into two branches before reaching the lungs. The lungs are lobed and filled with air sacs bounded by thin membranous tissues permeated with capillaries.

In taking in air the diaphragm is pulled backward by the contraction of its muscles and the walls of the thorax are expanded. These movements enlarge the thoracic cavity, which allows the air to rush into the lungs through the windpipe. An expiration is accomplished by the reverse movements.

Circulation. — The circulation of the rabbit is very similar to that of the sparrow. The heart is divided into two complete halves with the right auricle and right ventricle on one side and the left auricle and left ventricle on the other.

The blood flows from the different parts of the body into the right auricle and thence into the right ventricle. From the latter it is sent through the pulmonary arteries to the

lungs to be purified. The blood is returned from the lungs through the pulmonary veins to the left auricle. From here it flows into the left ventricle whence it is expelled through a system of arteries to all parts of the body (Fig. 204).

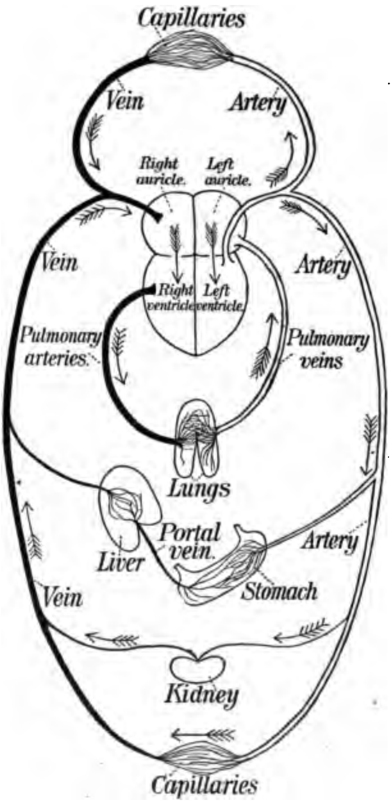

Fig. 204. — Circulation of a rabbit, showing the course of the blood. The dark vessels contain impure blood and the light vessels pure blood.

Excretory system.—The carbon dioxide and other waste materials gathered from the body by the blood is exchanged in the lungs for oxygen and expelled through the windpipe.

A pair of bean-shaped kidneys attached to the dorsal side of the abdomen gather the nitrogenous waste matters of the body and discharge them through the ureters into the urinary bladder.

Brain and spinal cord.—The surface of the brain is not greatly convoluted like that of the human brain, thus indicating a low order of intelligence. The brain consists of several distinct parts. In front is the *cerebrum*, made up of two large hemispheres, on the anterior extremities of which are the two club-shaped

olfactory lobes. Posterior to the cerebrum is the *cerebellum* composed of one centrally placed lobe flanked by lateral ones. Beneath the cerebellum and posterior to it is the enlarged end of the spinal cord, the *medulla oblongata.* The spinal cord extends through its channel in the backbone and gives off nerves to different parts of the body.

Reproduction and development. — The rabbit multiplies very rapidly. Several litters, each containing five or six or even more individuals, are produced in a season, and were it not for the fact that so many of the offspring die, these animals would overrun this country. The young are born alive and are nourished by the mother rabbit for a time on milk secreted by the milk, or *mammary glands.* These glands producing milk for the nourishment of the young by the mother is characteristic of all mammals.

Economic importance. — Rabbits often do serious injury to fruit trees by gnawing the bark from the trunks and girdling them, during the winter season when food is scarce. Occasionally, they injure gardens by eating the vegetables. Rabbits were introduced into Australia about 1860 and in a few years had multiplied to such an extent that they became a most serious pest and the Australian government has spent large sums of money trying to get rid of them. In parts of California these mammals occur in great numbers and cause serious injury.

On the other hand, the fur of the rabbit is used to make felt and nearly all of the "derby" hats are made from this material. The rabbit is also used for food to some extent in this country, especially by the negroes in the southern states.

Habits of the rabbit. — This mammal ranges from New England and Minnesota to Yucatan and because of its

abundance in all parts of this great area it is one of the most familiar of our wild mammals. It lives in fields overgrown with briers, among brush heaps, in wild plum thickets, along hedgerows, on the borders of woods, etc. Under ordinary conditions, a rabbit hollows out and smooths a place, called a "form," in some tuft of thick grass and passes its time here during the day. Its fur blends nicely with the dead or dying grass stems and the form furnishes a good hiding place. Sometimes rabbits enter burrows of other animals when hard pressed by their enemies, and occasionally they rest in hollow logs. In the winter they secure protection beneath brush piles and other shelters.

They are exceedingly timid creatures and have no effective organs of defense although they can scratch quite severely with their claws. They depend upon their senses of sight and hearing to detect their enemies and then upon their legs to escape. The color of the hair aids them in escaping observation.

XXV. MAMMALS (*continued*)

CHORDATA (*continued*)

THE EGG-LAYING MAMMALS (*Monotremata*)

Duckbill. — Living in Australia and the adjacent island of Tasmania is a curious and interesting animal known as the duckbill (Fig. 205). It is eighteen to twenty inches long, from the tip of its bill to the tip of its flat tail; and its body is covered with thick, dark brown fur, except on the bill and feet. The feet have five toes furnished with strong claws, and the toes are webbed. The webs of the front feet project beyond the claws, but can be folded back out of the way when the animal digs its burrow. While young, the animal has four or five teeth on each jaw; but in the adult these are replaced by horny plates.

FIG. 205. — Duckbill.

The duckbill spends much of its time in the water,

searching for grubs, worms, snails, and, most of all, mussels that live on the bottoms of streams. For a home, the animal digs a burrow in the bank of some stream. The burrow, which has one opening above and one below the surface of the water, extends in a winding manner gradually upward, and finally ends in a large cavity made by the parent for the nest, which is several feet above the level of the water, and, consequently, dry. The duckbill lays two or three true eggs, with soft, leathery shells. The young hatch from the eggs, and are fed by the milk secreted in the mammary, or milk glands of the mother. Hence this animal is a true mammal like the horse or the cow.[1]

Spiny ant-eater. — This animal is also found in Australia, but is smaller than the duckbill and differs markedly from the latter in habits and appearance. The ant-eater has its jaws produced into a narrow, bill-like structure and the upper surface of the body is covered with strong, pointed spines, between which are coarse hairs. The limbs are short and strong while every foot has five toes, each of which ends in a strong claw which enables the animal to burrow in the ground rapidly and efficiently.

The Pouched Mammals (*Marsupialia*)

Kangaroos. — There are several species of kangaroos, all of which are found in Australia and the near-by islands of New Guinea and Tasmania. Most of these mammals are terrestrial and live in the "bush" or in open places, browsing on the grass and tender shrubs. A few species, known as the tree kangaroos, actually climb trees and live in them. The largest kangaroo is the great gray kangaroo, sometimes

[1] Unlike the cow and horse the milk glands of the duckbill and spiny ant-eater have no teats or nipples.

called "old man" and "boomer." The male, when in an erect position on its hind legs, often measures over four feet in height and weighs two hundred pounds. The animal is very timid, yet when cornered, defends itself with spirit and effectiveness. When frightened, it covers from fifteen to twenty feet in one leap, and can easily keep pace with a swift dog. The fore legs are short, and are folded close to the breast when running, all the leaping being done with the strong hind legs, aided by the long, massive tail. Moreover, the tail acts as a balancing pole and enables the animal to maintain its proper position when in mid air.

FIG. 206. — Young opossum. Note its ratlike tail.

The smallest species are the rat kangaroos, some of which are only fourteen inches long.

The milk glands of the kangaroo are situated within a fold, or pouch of skin, on the ventral side of the abdomen. The young are born very immature, and are immediately placed by the mother in this bag, and are there carried for several months.

Opossum. — As with the kangaroos, there are several species of opossums; but the Virginia opossum, found from New York to Texas and south is the best known. The female has a pouch in which the young are carried for

some months. They are only about one half inch long when born, and are immediately put in the pouch by the mother. This opossum is about the size of a cat and is dirty white in color. It has a long, naked tail, like a rat's tail, and, for the most part, lives in trees.

The opossum and the kangaroo are examples of animals known as the *marsupials*. The pouch already spoken of, in which the young are carried, is called a marsupium, hence the name (Fig. 206).

The Toothless Mammals (*Edentates*)

Slôths. — These animals well deserve their name, for, as Dr. Gill says, "They are not only slow to move, but slow to think, slow to feel, and slow to die." They are strictly arboreal, spending their lives among the branches of trees and very rarely coming to the ground. The natural position of a sloth is to hang suspended by the long, curved claws from a branch, with the back downward. As some one has said, "He moves suspended from a branch, he rests suspended from it, and he sleeps suspended from it" (Fig. 207). They are often grayish in color, although some species are greenish, simulating very closely the leaves of the trees among which they

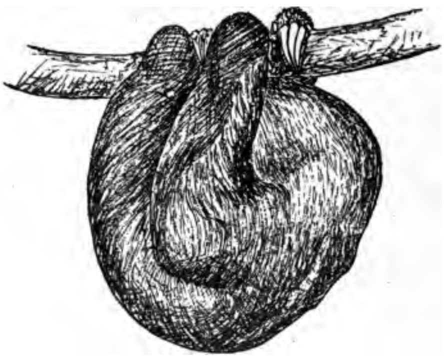

Fig. 207. — Sloth sleeping suspended from a branch.

live. The legs are comparatively long, especially the fore ones. When, for any reason, a sloth comes to the ground, it is exceedingly awkward, indeed almost helpless; for it can walk only with the greatest difficulty. They are found in the forests of South America, but some species come as far north as Nicaragua. The sloths are not large animals for they range in size from a good-sized cat to a fox or raccoon.

Armadillos. — Unlike the sloths, the armadillos are burrowing animals, and, accordingly, are fitted with strong

FIG. 208. — Three-banded armadillo: at the left, walking; at the right, rolled up for protection.

claws for digging. The back and sides of the body are covered with a coat of mail composed of thick, overlapping, bony scales. In some species even the head, also, is covered. This coat of mail is divided into three distinct portions, — an anterior portion covering the shoulders, a posterior portion covering the hips, and a middle portion, which is often divided into several distinct rings (Fig. 208). In the species shown, the middle portion is divided into three bands, hence this one is known as the three-banded armadillo. These breaks in the coating of scales afford flexibility, and give an opportunity for the animal to roll

up into a ball, as it often does for protection (Fig. 208). In the three-banded armadillo, the head also is covered with scales, which afford fuller protection. There is only one species of armadillo in the United States, and that is confined to Texas. It is about two and one half feet in length, and lives in burrows. None of the armadillos are large animals.

THE FISHLIKE MAMMALS (*Cete*)

Whales. — There are two distinct groups of whales, viz. those possessing strong functional teeth, — hence called

FIG. 209. — Jaws of a whalebone whale, showing the baleen.

the toothed whales; and those possessing no teeth in the adult stage, but having plates of "baleen," or "whalebone" which take the place of teeth, — hence known as the whalebone whales (Fig. 209). The sperm whale, found largely in the southern Pacific, southern Atlantic, and Indian oceans, is an example of the toothed whales. The males are often sixty and seventy feet long. Between the skin and skull,

on the right side of the massive head, is a large cavity containing the substance known as *spermaceti,* formerly used to a great extent in the manufacture of candles. The nostrils open by a single aperture through the top of the head. This opening is the "blow hole" and from it issue the columns of vapor sent forth by the animal when respiring. These huge animals come to the surface, "spout" — send forth moisture-laden columns of vapor from the lungs — sixty to seventy times, then plunge below to remain from forty minutes to an hour and a quarter.

There are several species of whalebone whales, but the bowhead, or Greenland whale is best known for its oil and whalebone. It has no teeth, but the lower sides of the upper jaw are furnished with hundreds of parallel plates of baleen, or whalebone. These plates are fringed at the end, and act very effectually as a strainer to separate the small animals, upon which the whale feeds, from the water taken in with them. The right whales of the Arctic Seas, the razor-back whales, and the sulphur-bottom whales are the largest living mammals. The latter are often ninety to ninety-five feet in length. The whales possess mammæ and suckle their young; but, superficially, they resemble fish more than mammals. The fore limbs are modified into paddles, while the hind limbs are wanting, and the body is incased in a thick layer of fat, the "blubber," which yields the oil so much sought after.

Manatee. — This is a curious mammal, forming a sort of connecting link between the whales and the hoofed mammals. The American manatee ranges from Florida to northern South America. It is still found in certain rivers of Florida, and is protected from extermination by state laws. The skin of this animal is smooth but has

scattering hairs. It is twelve to fifteen feet long and frequents the mouths of rivers. The molar teeth have flat crowns for grinding vegetation, for the manatee lives upon aquatic plants. The fore limbs are modified into paddles and the rounded, thin, flat tail acts as a propelling organ, while the hind limbs are wanting. The flesh of a closely related species is used for food by the South American natives.

There are certain sea cows, known as dugongs, found along the eastern coast of Africa and the coasts of India, Ceylon, and Australia. The Arctic, or Steller's sea cow, once inhabited the Arctic regions, but is now extinct.

The Hoofed Mammals (*Ungulata*)

The hoofed mammals may be divided into three groups: those that possess an odd number of toes, the horse, zebra, ass, tapir, and rhinoceros; those with an even number of toes, giraffe, camel, deer, oxen, hog, and hippopotamus; and a third group including those that have a trunk, or proboscis, represented by the elephant.

It is a curious and interesting fact that the hoofed mammals walk on the ends of their toes, which, however, are incased in a horny covering called a hoof. The hoof is a modification of the skin.

Among the odd-toed mammals are the tapirs that live in the tropical forest regions of both continents. They resemble hogs in appearance and form, but have a large, prehensile upper lip.

The rhinoceroses, which have three toes on each foot, are found in Africa and Asia. They have a very thick skin which, in some species, is thrown into folds. The snout

bears one or two horns quite different in structure and origin from those of cattle. The Indian rhinoceros has one horn; while the black rhinoceros of Africa has two, one situated in a line directly behind the other. The white rhinoceros of Africa is a huge beast rivaled in size among the land animals by the elephant only.

The horse has only one toe, but the so-called "splint bones" are the existing remnants of a second and a fourth toe. In the western states a remarkable series of fossils have been found showing the development of the horse from forms about the size of a fox with three toes behind and four toes in front.

The even-toed group of hoofed mammals have as their lowest representative the hippopotamus, of which there are only two species, both found in Africa. They have four toes, a huge, ungainly body, and large canine teeth developed into tusks. They may be seen in large herds in the rivers of Africa, in the daytime, apparently for the simple pleasure of being in the water. They can remain beneath the water for a considerable interval of time, and to facilitate such a habit the nostrils can be closed by muscular contractions. They live on aquatic plants and the herbage along rivers.

Certain species of the even-toed mammals differ from the hippopotamus in the structure of the stomach and in the manner of masticating the food. For example, an ox, sheep, camel, deer, etc., are said to "chew the cud." Therefore, these mammals are known as ruminants.

The stomach of a ruminant is divided into four compartments, known, respectively, as the *rumen*, or paunch; the *reticulum*, or honeycomb; the *psalterium*, or book; and the *abomasum*, or stomach proper (Fig. 210). While an ox is

grazing, the food is swallowed without mastication, and, together with saliva, passed directly into the rumen, or paunch, and reticulum. After the animal finishes eating, the food is brought back to the mouth — a small quantity at a time, which constitutes the cud — and is thoroughly masticated. This time, after being swallowed, the food goes to the psalterium, and thence to the abomasum, or

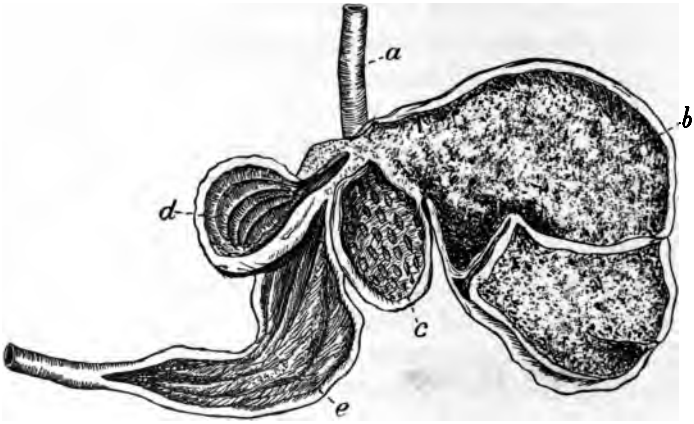

FIG. 210. — Stomach of a ruminant: *a*, gullet; *b*, rumen; *c*, reticulum; *d*, psalterium; *e*, abomasum.

fourth stomach, where the gastric juice is mixed with it. To the ruminants belong most of our valuable domesticated animals.

Although the camel is a ruminant, its stomach has only three compartments, the psalterium not being present. The dromedary has one hump and its body is covered with a fine wool hair, except on the breast and knees, the latter being covered with thick pads of skin. This is the beast of burden used in traveling across the deserts of Africa and Arabia. It is expected to go from three to five

days without water during these journeys, but ordinarily demands water every other day. On the under side of each of its feet is a large spongy pad which enables the animal to travel over the sand with comparative ease. The camel inhabiting central Asia has two humps.

The llamas and alpacas, found in the western parts of South America, are members of the camel family. The llama is still used as a beast of burden, while the alpacas are reared for their wool which is used in the manufacture of dress fabrics.

The third group of ungulates is represented by the elephants. There are only two representatives of living elephants, the African and the Asiatic. The former is wild, and valued for the ivory of its tusks. The latter is domesticated and is usually docile and intelligent. The head of the elephant is very large, and would be almost insupportable from its enormous weight were it not for the fact that the bones of the head contain cells filled with air.

The upper incisor teeth are greatly developed and form the tusks. The neck is very short, but the snout is prolonged into a long flexible trunk, or proboscis. At the end of the trunk are the openings of the nostrils, which are overarched by a small fingerlike process. The trunk is a wonderfully mobile and versatile organ. In it Cuvier counted twenty thousand muscles, became discouraged, but estimated the number to be forty thousand. With it the elephant can lift a cannon, or pick up a lozenge or brush off a fly or uproot a tree.

Flesh-eating Mammals (*Feræ or Carnivora*)

If we have observed closely, we have seen that the hoofed mammals were distinctly plant-eating, or herbivorous

animals. We now come to a group of animals that are distinctly flesh-eating, or, as they are called, carnivorous. The teeth are fitted for cutting or tearing rather than for grinding, and the stomach is single.

Fig. 211. — Raccoon.

The flesh-eating mammals are represented by the raccoon, bear, lion, tiger, dog, cat, wolf, etc.

The raccoon is widely distributed over the United States and is commonly known by the simple appellation of "coon" (Fig. 211). It will eat almost anything from green corn to oysters. The body is clothed with thick gray fur mixed with black, and the tail is long, large, and cylindrical, and ringed with gray and dark brown.

The black bear, which is found over the greater part of the United States, is known as a "plantigrade" animal because it walks on the whole sole of its foot. Like the coon, it is somewhat of a vegetarian and is fond of berries,

acorns, and nuts as well as of lambs, pigs, and calves. Generally speaking, it hibernates during the winter.

The grizzly bear, which lives among the Rockies, is the most ferocious and largest of the bears. It often weighs six to eight hundred pounds.

The lion (Fig. 212) is simply an enormous cat; it is sometimes called "king of beasts." The light, springy, silent

FIG. 212. — Lion in the act of springing. Redrawn, by permission, from an illustration by Knight in *McClure's Magazine*, 1900.

step and graceful, almost majestic stride of the lion differ markedly from the clumsy, heavy step of the bear. A lion may attain a weight of six hundred pounds.

The tiger is a beautiful and magnificent cat found in southern Asia from Persia to India, and in the Malay Peninsula and the adjoining islands of Sumatra and Java. It equals and, it is said, exceeds the lion in size; without question, it exceeds the lion in strength and ferocity.

The Fin-footed Mammals (*Pinnipedia*)

The fur seal.—Really, the fur seal (Fig. 213) belongs to the family of sea lions. The true seals have short necks and fat bodies, while the sea lions have longer necks and are much more active in the water and on land.

Fig. 213.—Fur seal.

The fur seal is very interesting because of its habits and economic value. The full grown male seal weighs from four hundred to five hundred pounds; but the female is much smaller, often not weighing over one hundred pounds. The legs of this mammal are flat and wide, and the toes are united to form paddles for swimming, although the hind limbs serve to scramble about over the rocky beaches.

Once a year all the seals, young and old, repair to the Pribilof Islands in the Behring Sea. The males arrive first in April and May, and in June the females begin to come. Certain suitable rocky shores of these islands that are literally covered with the seals are known as the "rookeries." In 1870 there were estimated to be several million seals on the Pribilof Islands, but the number is rapidly diminishing. The bachelor seals, or "holluschickie" are the only ones now allowed to be slain, and it is these that furnish the skins for the market.

By October and November, the great majority of the seals have left the islands, not to return until the following spring. The time between the visits is spent in the open

ocean, the seals seldom, if ever, touching land in all this time.

Walruses. — These are aquatic mammals of strange appearance and peculiar habits (Fig. 214). A male walrus is a huge beast, ten to twelve feet long and weighing from eighteeen hundred to two thousand pounds. The canine teeth are developed into huge tusks sometimes two feet in length. These animals are active in the

Fig. 214. — Walrus.

water, but on land they are well-nigh helpless and can be easily approached and killed. They inhabit the northern Atlantic and Pacific oceans and are of great use to the natives around Behring Strait. The flesh is used for food, the skins for roofs of houses, for dog harnesses, and for fishing lines. The tusks are used for making implements and are sold in trade.

The Gnawing Mammals (*Rodentia*)

Technically, these animals are known as the *Rodentia*, or rodents, — both words being derived from the verb *rodo*,

gnaw. In this group are included the rat, mouse, rabbit, woodchuck, squirrels, etc.

The teeth of the rabbit have already been described and their fitness for gnawing has been explained. The rat, which, perhaps, is a more typical gnawer, has only two incisors on the upper jaw, but they meet the incisors on the lower jaw in the same manner as do those of the rabbit and are kept sharp in the same way. Keeping, then, the general form and peculiarities of a rodent's teeth in mind, as exemplified by those of a rat and rabbit, we shall pass to others of the group.

FIG. 215.—Porcupine in tree top. Redrawn from an illustration by Dugmore in *McClure's Magazine*, 1900.

Porcupines.—These animals are also gnawers, and the species found in the United States are more or less arboreal (Fig. 215). The Old World porcupines are strictly terrestrial. Porcupines are covered with coarse hairs among which are the spines, or quills, which constitute a notably efficient means of defense. When on the defensive, a porcupine arches its back and rolls up into a ball. The tail, which is thickly covered with spines, is the main organ of defense. The

unwary dog or person worrying the porcupine is often caught within striking distance. The spines are rough and jagged at the ends, but sharp, and when they once enter the flesh, tend to work farther in.

Prairie marmots. — These little animals, better known as "prairie dogs," are closely related to the woodchuck of New England and the middle states. The best-known species is found on the prairies west of the Mississippi River. They live in colonies and dig deep burrows in the ground. The great quantities of earth brought up in digging these holes are piled in a mound near the mouth of the burrow.

Beavers. — The beaver is one of the largest and heaviest rodents, often weighing thirty to fifty pounds. The body is covered with a thick coat of soft fur beneath a layer of longer coarse hair. The hind feet are webbed for swimming, but the fore feet are fitted for digging.

Moreover, the beaver is one of the greatest gnawers of the whole group. It lives in colonies and is very industrious; but most of its work is done at night. The houses, or "lodges," of the beaver are built on the edge of the water, are dome-shaped, and some four or five feet high. They are built of stones, sticks, and mud, and are finally plastered over in the autumn with mud, which freezes, thus forming a hard impenetrable shell. The opening into the lodge is beneath the water. The living apartment is at the top, above the water line; but near by are stored branches of trees, the bark of which serves for the winter food. In order to maintain the water at the desired height about their lodges, the beavers build dams of considerable length (perhaps the longest ever noted being three hundred yards) across streams, with the convex side upstream, to withstand the pressure. The dam

is built of sticks, stones, and mud, not in regular fashion, yet forming a water-tight and very firm barrier.

INSECT-EATING MAMMALS (*Insectivora*)

The mammals of this group live on very small animals, mainly insects, and for this reason are called *Insectivora* (*insectum*, insect; *voro*, eat). The molar teeth are fitted for crushing insects' bodies. To this group belong the shrews, moles, hedgehogs, and some other little-known mammals.

Shrews. — These are the smallest of mammals. One species known as the *least shrew*, which measures only a trifle over two inches in length, is surely quite a contrast with those other two gigantic mammals, the elephant and the whale. The shrews greatly resemble small mice. The body is covered with a coat of soft, furry hair; but the eyes are small and often hidden in the fur, for these animals burrow beneath the surface of the soil and are not often seen by day. They live largely in the woods, and some species are aquatic.

Moles. — Probably the moles are the best-known mammals of the insectivorous group. They are often held responsible for serious injury when, in reality, they do more good than harm.

The shoulders and fore legs of the mole are very short and stout; and the fore feet are broad and shovel-like, with each toe ending in a strong, sharp claw. Thus the animal is fitted for digging. The nose is long and slender, and the body is covered with a very fine, soft, dense coat of hair. Since the mole lives in the earth, it has no need for well-developed eyes. In fact, the eyes are situated beneath the skin and serve only to distinguish daylight from darkness.

Like the shrews, the mole lives on earthworms, insects, and the larvæ of insects, or "grubs," that exist in the soil. To obtain these, it becomes necessary to burrow here and there through the soil. Hence the burrows made by the mole are dug in quest of worms and "grubs," and not of seeds or roots.

The hedgehog is an Old World mammal belonging to the Insectivora. It has spines on its body, and when attacked, rolls up into a ball like the porcupine. The largest may slightly exceed a large rat in size. The term *hedgehog* is often applied to the porcupine, which we have already studied in the group of gnawing mammals.

Winged Mammals (*Chiroptera*)

There are nearly four hundred and fifty species of this order of mammals, and they are found in various parts of the world. The bats vary in size and appearance. The largest species are found in tropical countries.

Common bats. — The best-known members of this order are the small or medium sized bats so common everywhere in the United States (Fig. 216). Perhaps the little red bat and the small brown bat are the most common species. The fore limbs which constitute the wings, or organs of flight, have the bones of the fingers and hand greatly elongated, spread far apart, and covered by a leathery membrane, which extends along the sides of the body to the hind legs. Only four of the fingers are included in the wing. The fifth is free and forms a sort of hook, or claw (Fig. 230). The membrane covering the fingers and forming the wing is nearly or quite devoid of hair. The bodies of bats are so much like those of mice, in general, that the Germans call

them "flitting mice." The eyes are small, but the ears are large, and the sense of touch is acute. The hind legs are small and weak.

The common bats are nocturnal in habits. During the day they remain hidden in a hollow tree, cave, or dark recess, coming forth to seek their prey at twilight and night.

Fig. 216. — Bat.

Those bats that live in cold climates and do not migrate, hibernate during the winter.

The fruit-eating bats found in India, Ceylon, the Malay Archipelago, and eastern Australia are of large size and have foxlike heads with large eyes and are diurnal in habits. They feed almost exclusively upon fruits. The fruit bats or flying foxes of Ceylon often have a wing expanse of forty inches. They frequently live in colonies of fifty or more individuals.

In the valleys of the Amazon and in other parts of South America are found the true vampire bats. These actually suck the blood of wild animals and in some localities cause considerable injury to domestic animals. Moreover, the

vampires often bite human beings on the nose or feet while asleep at night. These bats are all small, their bodies measuring less than four inches in length.

THE FIRST MAMMALS (*Primates*)

We have finally reached the highest group of mammals and, at the same time, the highest group of animals in the kingdom. They are, therefore, known as the Primates. The primates include the lemurs, monkeys, baboons, chimpanzee, orang-outang, gorilla, gibbon, and man.

The lemurs are apelike mammals living in India, tropical parts of Africa, and the Island of Madagascar. They are the lowest members of the Primates. The baboons are found in Arabia and Africa and usually live in troops, often raiding plantations at night. They are fond of berries, tamarinds, and other fruits, but usually destroy and carry away more of these fruits than they eat. They are repulsive animals and their faces resemble that of a dog, while they can walk easily and handily on all fours.

The orang-outang is one of the four primates that stand nearest to man, the other three being the gibbon, chimpanzee, and gorilla. The orang-outang is found in the low swampy parts of the Island of Borneo and rarely in Sumatra. It is about four feet six inches high, is strictly arboreal, and travels by swinging from branch to branch. It constructs a rude nest in trees some twenty or thirty feet from the ground.

The chimpanzee, in general appearance, is more like man than any other of the tailless apes. It is found in central and western Africa and even north to the Sudan. The body is more or less covered with a coat of shiny, thick

hair, very dark, nearly black in color. It is a good climber and makes its nest of sticks and broken limbs in the forks of branches of trees ten or twenty feet above the ground.

The gorilla is the largest of the manlike apes, often reaching a height of five feet, four or six inches. It lives in deep forests, in a very restricted portion of western Africa in the Congo district. Its forehead retreats strongly, its expression is brutal, and the body is more uniformly covered with hair than that of the chimpanzee. The gorilla naturally walks on all fours but it can walk erect although rather clumsily. Its ferocity has been exaggerated.

Man. — As an animal, man belongs to the family Hominidæ and is known scientifically as *Homo sapiens*. As an animal, he is distinguished for his erect posture, very complete opposition of the thumb to the fingers, short canine teeth, greater length of hind, as compared with fore limbs, and the great size and complexity of the brain.

Characteristics of the mammals. — As we have already learned, the name of the class is derived from the fact that the young are nourished for a longer or shorter time on milk, which is a fluid secretion from certain specialized glands known as mammæ. Secondly, it may be said that the bodies of mammals, at some period of their existence, are more or less covered with hair. We have seen from our own study and observation that many are completely covered with hair, except the nose and soles of the feet. On the other hand, the whales are wholly destitute of hair, or very sparsely clothed with it, in the adult stage; but it is present on portions of the body in embryonic whales. Moreover the heart, as in birds, consists of four chambers, the two on one side being completely separated from the two on the other side. Hence, there is a double circulation. The

thorax is separated from the abdomen by a strong muscular partition known as the diaphragm. This aids greatly in respiration. The mammals, in general, bring forth their young alive. We found exceptions in the duckbill and the spiny ant-eater, both of which lay eggs.

Upward progression among the mammals. — The duckbill, the lowest mammal, ushers in the class. Superficially, this animal resembles a bird so that one might think the Mammalia more closely related to the Aves than to any other class among the vertebrates. Modern zoölogists are, however, inclined to think the mammals had for an ancestor some animal of very strong reptilian characters, because the duckbill and spiny ant-eater possess reptilelike characters. Whatever kind of an ancestor mammals had, they show a great advance over any other group of animals in complexity of structure. A most important advance among the mammals themselves is a constant tendency for the body to develop headward. The brain becomes larger and larger and the fore limbs become modified into hands for grasping, exemplified in man. Moreover there is a development among the mammals toward an upright position, again exemplified in man. This "holding up of the head" seems to go along with the increase in size of brain. The complexity of the teeth and the structure of the limbs show a decided step in advance over the birds and reptiles.

Adaptations to environments among the mammals. — Whatever forces compelled the duckbill to live the life it does, other forces just as surely molded and adapted it to that life. Its food is found mainly under water, and to obtain this food, the duckbill is obliged to remain submerged some time. Consequently, although a terrestrial

animal, it has become adapted to staying beneath the water some six or seven minutes at a time. Its feet are webbed for swimming, yet the web on the front pair can be turned back out of the way, thus exposing the claws so necessary for digging its burrows. The spiny ant-eater is furnished with strong claws for tearing open the ants' nests. In addition, it has a long, sticky, extensile tongue with which it can lick up the ants by the hundred and thus obtain a meal.

The sloth passes its existence in trees. Yet how curiously adapted to such a life it is. What wonderful muscles it must have never to weary of hanging down, either in its waking or sleeping moments. Try the experiment of holding your own weight by suspending yourself from a bar, by your arms, for five minutes. It will give an idea of what the sloth's mode of life means to its muscles. Note that the claws are also modified for grasping the branches. Many sloths possess hair resembling leaves in color, thus affording them protection. I suspect they were driven to such a mode of living partly for the sake of protection. The armadillo, however, which belongs to the same order, instead of climbing trees took upon himself a coat of armor, so flexible that he can roll up inside of it for protection.

Perhaps among mammals the most remarkable modifications and adaptations are found among the whales. As a class, mammals are terrestrial; but here we find an order which is wholly water-living. They are so far modified as to have lost one pair of legs, wholly unfitting them for a terrestrial life; and the second pair is modified into very efficient paddles. Again, the tail is adapted to swimming, and the body is covered with a very thick layer of fat to protect them from the intense cold met with in their habitats.

The bowhead whale has no teeth and a very small throat, hence cannot live on large animals or on gross vegetable bodies. It, however, has an enormously capacious mouth with which it takes up great quantities of sea water containing countless numbers of small animals. It would be unpleasant and not economical to swallow such mouthfuls of sea water. Consequently, in place of the teeth, there grow these filaments of whalebone from the upper jaw that act as a strainer in allowing the water to escape, retaining the myriads of small animals for food.

An elephant's trunk is wonderfully well adapted to the needs of that animal. The great tusks prevent the animal from reaching the ground with its mouth to pick up food; but the trunk with its innumerable muscles forms a grasping organ of wonderful delicacy and flexibility with which anything from hay to peanuts or bits of candy may be conveyed to the mouth.

The members of the cat family catch their prey by slipping up and pouncing upon it unawares. For holding their prey securely the toes are provided with very sharp, hooked claws. However efficient and necessary these claws are, they would nevertheless be of very great inconvenience were they prominently protruding from the feet. The claws would catch in various objects, causing noise, stumbling, and all sorts of annoyances. To avoid this, they can be retracted into the folds of the skin and hair, where they cannot cause unexpected trouble; and at the same time this retraction makes possible the still, noiseless tread so characteristic of cats.

If the whales stand first as showing the most remarkable modifications of structure to suit their environments, then the bats ought to stand very close to them. It is very

remarkable that a mammal clothed with hair and without feathers should still be capable of very perfect flight. Moreover, the bats fly in the night time and do not have highly developed eyes, yet they are so adapted to nocturnal flight, because of the great development of the tactual sense in the wing membranes, that they easily avoid the objects in or near their path. Indeed, it is said, they could do this were they totally blind. Again, in most mammals, we find the hind pair of legs the stronger; but in the bats, the front pair is the stronger and better developed, which is a direct adaptation for flight, since it is these that are mainly concerned in flight.

Instances of adaptations among the mammals are almost without end, and our space forbids mention of more. Much pleasure and profit may be derived from a study of the habits of mammals and of the adaptations to meet the demands of their environments.

CLASSIFICATION OF THE MAMMALS

Class — Mammalia.
- *Subclass I* — Prototheria.
  - Order — Monotremata.
    - Types of Order.
      - *Ornithorhynchus anatinus* — Duckbill.
      - *Tachyglossus aculeatus* or *Echidna aculeata* — Spiny ant-eater.
- *Subclass II* — Theria.
  - *Section A* — Metatheria or Marsupialia.
    - Order — Polyprotodontia.
      - Type of Order.
        - *Didelphys virginiana* — Opossum.
    - Order — Diprotodontia.
      - Type of Order.
        - *Macropus giganteus* — Kangaroo.

Section B — Eutheria.

Order — Edentata.

Types of Order.

Cholœpus Hoffmani — Two-toed sloth.

Tolypeutes tricinctus — Three-banded armadillo.

Order — Cetacea.

Types of Order.

Physeter macrocephalus — Sperm whale.

Balœna mysticetus — Greenland whale.

Delphinus delphis — Dolphin.

Order — Sirenia.

Types of Order.

Trichechus latirostris — Manatee.

Dugong australis — Dugong.

Order — Ungulata.

Types of Order.

Rhinoceros unicornis — Rhinoceros.

Hippopotamus amphibus — Hippopotamus.

Bos (several species) — Ox.

Camelus dromedarius — Dromedary.

Camelus bactrianus — Two-humped camel.

Lama llama — Llama.

Lama pacos — Alpaca.

Elephas africanus } Elephant.
Elephas indicus }

Order — Carnivora.

Types of Order.

Procyon lotor — Raccoon.

Ursus americanus — Black bear.

Ursus horribilis — Grizzly bear.

Felis tigris — Tiger.

Felis leo — Lion.

Order — Pinnipedia.

Types of Order.

Phoca vitulina — Seal.

Callotaria ursina — Fur seal.

Odobenus obesus — Walrus.

Order — Rodentia.
- Types of Order.
  - *Mus norvegicus* — Rat.
  - *Erethizon dorsatus* — Porcupine.
  - *Cynomys ludovicianus* — Prairie dog.
  - *Castor canadensis* — Beaver.
  - *Lepas sylvaticus* — Rabbit.

Order — Insectivora.
- Types of Order.
  - *Sorex personatus* — Shrew.
  - *Scalops aquaticus* — Mole.

Order — Chiroptera.
- Types of Order.
  - *Lasiurus borealis* — Red bat.
  - *Myotis subulatus* — Brown bat.
  - *Phyllostoma hastatum* — Vampire.
  - *Pteropus edwardsi* — Fruit-eating bat.

Order — Primates.
- Types of Order.
  - *Lemur macaco.*— Lemur.
  - *Cynocephalus anubis* — Baboon.
  - *Simia satyrus* — Orang-outang.
  - *Pan troglodytes* — Chimpanzee.
  - *Gorilla gorilla* — Gorilla.
  - *Homo sapiens* — Man.

XXVI. ANIMALS OF THE PAST

The signs that indicate the existence of prehistoric animals. — There are signs, or indications, scattered over the earth that denote the past existence of a great host of animals different from those now living. This vast assemblage of curious and interesting forms was born, lived, and died before the present species came to inhabit the land and seas. The signs left by these prehistoric creatures consist of bones, teeth, footprints, shells, and skeletons that are found in the rocky structure of the earth, in quarries, railway cuts, beds of streams, and in many other places. We call these signs by one comprehensive term, *fossils*. It is by means of fossils that we have been able to learn something of this mighty and ancient host; and any discussion of the animal kingdom would be incomplete without mention of these bygone forms.

Eras of the earth. — Briefly, geologists divide the past history of the earth into four great chapters, or, as they are called, *eras*. These are in their order, beginning with the oldest, as follows: archean, paleozoic, mesozoic, and cenozoic. From a zoölogical standpoint the archean era is characterized by a noticeable lack of fossils or any absolute indications of animal life. The paleozoic era is prominent as an age when invertebrates existed, while the mesozoic is characterized by its great number of reptiles. Finally, the cenozoic, or last era, is known as the age of mammals.

Animal Life in the Archean Era

The word *archean* means beginning. Therefore, this era covers the time of the beginning of the earth's crust and of the formation of the oldest rocks. At this time, we hardly dare say how long ago, most of the surface of the earth was covered with water, and there were no varied and forest-covered landscapes to greet the eye. In fact, so far as we know, there were no plants large enough to be visible to the unaided eye. Indeed, it is not certain that any plants existed. The same thing may be said of animals. Almost no sure signs or fossils of animal life have been found to show that animals existed then. If animals did exist in the archean age, they must have been small and probably had soft bodies like the amœba and so were not preserved.

There are some things, however, that lead geologists to think that life did exist in the archean time. For example, beds of iron ore and crystalline limestone are found in rocks of this era, and these are usually formed through the agency of life, but not always. Hence these deposits of iron and limestone are not clear proofs. It is also thought that some very obscure fossils of a low animal have been found; but here again certainty cannot be said to exist. The thing that can be stated with surety is, that at the very beginning of the next era, the paleozoic, there was an abundance of animals of the lower types. Now, since it is positively known that animals came into existence through a gradual course of development rather than by a sudden, simultaneous appearance, we shall have to conclude that life did exist in the archean era, since it was so abundant at the beginning of the paleozoic. For some reason, all of this life and all of its records have been blotted out.

Animals of the Paleozoic Era

Now we find ourselves on very much surer ground. At the ushering in of this era the waters of the earth were teeming with myriads of animals, all invertebrates. Later in the era, for it was very long, the first of the fishes — an ancient type — some amphibians, and a few primitive reptiles came in. So, after all, the vertebrate animals appeared rather early in the geological history of the earth.


FIG. 217. — Trilobite.

Trilobites. — The most important animals of the early paleozoic were the trilobites, members of the branch, Arthropoda. The bodies of these animals were divided into three longitudinal lobes, separated by two furrows, sometimes deep and sometimes shallow and obscure (Fig. 217). The trilobites possessed numerous jointed append-


FIG. 218. — Group of cup corals.

ages, and varied from less than an inch to two feet in length. They were exceedingly abundant in the first half of this era, but later slowly declined in numbers and variety until they passed out of existence by the beginning of the mesozoic era, never to reappear.

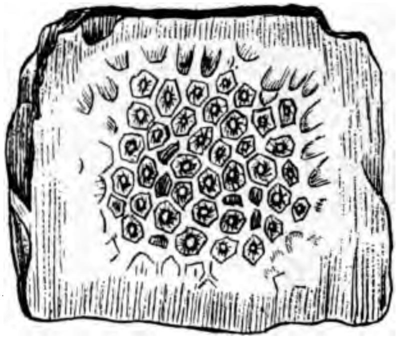

FIG. 219. — Honeycomb coral.

Lamp shells. — Perhaps the next most important group of animals was the lamp shells, or brachiopods. They were also very numerous in the seas at this time. This group differs from the trilobites in never having entirely passed out of existence, because some species, almost unchanged, are living at the present day.

Corals. — There were corals also in those days. These were mainly of three kinds: the cup corals, honeycomb corals, and the chain corals. Their names indicate something of their shape and appearance. The cup corals were single, solitary polyps or groups of polyps, each more or less cup-shaped (Fig. 218). The honeycomb corals were groups of polpys, each more or less polygonal in shape, hence resembling a honeycomb (Fig. 219). The appearance of the chain corals may be seen

FIG. 220. — Chain coral.

from Figure 220. It must be remembered that these are all quite different forms from the corals living to-day.

FIG. 221.—Crinoid.

Crinoids. — Then there were the crinoids, or sea lilies (Fig. 221), members of the star-fish branch. Here, again, we have an example of a group of prehistoric animals some representatives of which are living to-day, for a crinoid is sometimes dredged from the sea even now. They were much more abundant then than at present.

Mollusks. — Numbers of the mollusks existed all through the paleozoic era. They were unlike the mollusks of to-day and were probably not edible. One of them, the Orthoceras, possessed a straight, tapering shell, chambered like the shell of the pearly nautilus (Fig. 222). In fact, this animal belongs to the same class as the nautilus and squid. The Orthoceras varied from a few inches to ten or twelve feet in length.

FIG. 222.—Orthoceras.

Insects. — In the early part of the paleozoic era we find signs of insect life, if we may call a scorpion an insect. More than this, the scorpion is the first air-breathing animal found in the rocks of America (Fig. 223). Later on, in

Fig. 223. — Fossil scorpion.

the great coal-forming period of this era, we find traces of spiders and several kinds of insects; namely, locusts, cockroaches, and dragon flies.

Fishes. — Fossils are found indicating that fishes came into existence early in the paleozoic era, although not at the beginning. These ancient fishes were very different from those living to-day. Their bodies were, for the most part, covered with bony plates or smooth, hard, inflexible scales, quite unlike the scales on living fishes.

Fig. 224. — Paleozoic fish.

Fig. 225. — Paleozoic fish.

ANIMALS OF THE MESOZOIC ERA

In this era the reptiles increased in size, variety, and number. Fishes, insects, and mollusks became abundant and various, and more nearly approached the living forms of these groups. Sea urchins (Fig. 226) much like our present ones appeared in abundance. The lamp shells diminished in number of species, but the squids, cuttlefishes, and other mollusks appeared and peopled the seas. Their shells are found in immense numbers and are well preserved. The trilobites having disappeared, crabs and lobsters came in their places.

FIG. 226. — Sea urchin of mesozoic times.

Reptiles. — It is among these animals that the greatest changes are noted. There existed at this time three classes of reptiles: land reptiles, sea reptiles, and flying reptiles. They were very abundant and of extraordinary size and variety.

FIG. 227. — Sea reptile of mesozoic times.

The remains of about fifty species of sea reptiles have been found. Some of them were thirty to forty feet long.

FIG. 228.—Sea reptile of mesozoic times.

Figure 227 gives a very good idea of the appearance of one species. Another species shown in Figure 228 varied from twenty-five to thirty feet in length.

FIG. 229.—Land reptile of mesozoic times.

It is among the land reptiles that we find the hugest animals. Some of them were even larger than the elephant and moved sluggishly. Many of them were herbivorous, cropping the branches of trees, while others were carnivo-

FIG. 230. — Land reptile of mesozoic times.

rous, killing their fellows. Some of them had huge hind limbs on which they walked, dragging an immense tail behind, and holding the small front legs up like a kangaroo (Fig. 229). The one shown in Figure 230 walked on all four

FIG. 231. — Flying reptile of mesozoic times.

legs and was sometimes sixty feet long. A species of land reptile found in Colorado attained a length of seventy to eighty feet.

More curious still were the flying reptiles. These were a

strange combination of bird and reptile. The bones were hollow, but there were no feathers on the body. Their wings were leathery like those of a bat; and sometimes they had a long tail ending in a flap. Figure 231 gives an idea of their appearance.

Figure 232 shows a remarkable reptilelike bird just as its outlines were found impressed on the rocks. It had wings,

FIG. 232. — Reptilelike bird of mesozoic times.

and the whole body was covered with feathers; but the mouth, like that of a reptile, had teeth, and like a reptile it had a long, jointed tail with feathers along the sides in pairs. This seems to indicate that the reptiles and birds have sprung from the same ancestors.

Birds. — Birds appeared during the mesozoic era. Some of them had teeth and some of them had none. They varied in size from small birds to those having a height of

six feet. Many of them had no wings but depended on their strong legs for locomotion.

Mammals. — As we have already said, these are the highest animals on the earth. They appeared for the first time in the early mesozoic. But the first representatives were of a low type; and the earliest that have been found in this country belong to the marsupials and monotremes, the same groups as those to which the kangaroo and duck-bill belong, respectively. Toward the end of the mesozoic higher types of mammals came into existence.

Animals of the Cenozoic Era

We have seen how life began with very low forms in the archean, and gradually grew higher and higher by the ex-

Fig. 233. — Mammoth. Redrawn, by permission, from an illustration by Knight in *McClure's Magazine*, 1900.

tinction of old and low forms and the formation of new and higher forms, until now, in the beginning of the cenozoic

era, we find a great similarity to the life as it now exists. The great advance in this era was the remarkable development of mammals. The great reptiles disappeared and mammals took their places. In the ocean we find huge whalelike creatures seventy feet long. Remains of the Zeuglodon have been found in great abundance in Alabama. The early ancestors of the cat, panther, wolf, etc., appear in this era. The elephant family was represented by the huge mammoth (Fig. 233) and mastodon, neither of which, however, was much if any larger than some of the largest living elephants. Insects and birds were abundant in this era. Monkeys, horses, and rhinoceroses appeared in the cenozoic. Later came the buffaloes, hyenas, elks, etc.

The coming of man marked the climax in the progress of life upon the globe. Just how, or just when he came, we do not know, but we have sure proof that he has existed upon the earth many thousands of years.

Significant features of the history of animal life on the earth. — It has been the attempt of the author to show that the present animals on the earth are all connected with one another, from the lowest to the highest, by intermediate forms, and that all life has gradually arisen from a very simple, probably one-celled animal. In examining the history of the appearance of animals on the earth, we find the same thing to be clearly evident. The first form of life we found was very simple indeed, and lived wholly in the water. This was succeeded in a later age by higher life that finally came to live on land. This, in turn, was succeeded by higher and higher and more varied forms, until it culminated in the appearance of man, the crowning feature of life.

XXVII. THE STRUGGLE FOR EXISTENCE

The great number of animals born that never reach maturity. — Pools of water are often seen that are literally black with tadpoles. Is it possible that all of them become full grown? If so, the earth would become alive with toads, because there are thousands upon thousands of pools containing polliwogs. Many insects increase in an enormous geometrical ratio and if all lived, no other animals could exist on the earth. A female codfish deposits from two to six millions of eggs in one season. If all these hatched and the young cod grew to maturity, the ocean would soon be so full that no other fish could find room to live. It is plain then that myriads of animals are born that never reach maturity.

The struggle for existence and survival of the fittest. — Ever since animals appeared on the earth they have been constantly struggling with one another and with their surrounding conditions to maintain their existence on the earth. Some tadpoles are stronger than others from the start. These stronger ones are able to swim more rapidly, hence are able to catch their food before the weaker ones can get to it. In this way the strong ones grow stronger, and the weak ones weaker, and in the end, only a few of the hardier tadpoles are left to reach maturity. It is much the same with the insects. Some are better fitted to obtain food than others, and some are better protected from their enemies and escape being devoured, while others travel far

and meet with less unfavorable surroundings. Thousands of the cod's eggs never hatch and thousands of the young cod die from disease, while others are killed; so that but a few finally become full grown. The question naturally arises, how do any reach maturity and live?

After long years of patient observation, a law known as the "survival of the fittest" has been enunciated and apparently established. The tadpole and the young codfish that could swim the fastest and had the strongest jaws were best able to procure food and most likely to survive. All animals that are best fitted to meet their surroundings are the ones that are most apt to live. In other words, these are the *fittest animals*, and it is these that reach maturity.

Adaptations to surroundings. — Wherever we may go to observe animals, we shall find that the surviving ones are those best adapted to their surroundings. For example, a tiger with its short hair could not withstand the climate of the polar regions so well as the polar bear with its long, shaggy coat. The common toad could not exist on the deserts of the great Southwest, but the horned toad and the Gila monster prefer these regions because they are adapted to them.

Moreover, animals are being constantly modified and molded to suit their changing environments. We do not often recognize these changes because they are slight and very gradual; nevertheless, they amount to a great deal in a long series of years. For example, many insects have been known to change from one kind of food plant to another after the former had been destroyed. The same species of insects and reptiles often differ greatly in color when living upon different colored plants or upon earth of different shades, probably to gain protection from their

enemies. In other words, animals are constantly being changed, or adapted, to meet their surrounding conditions; and those best adapted to their environment are most apt to survive.

Resemblances. — No matter how closely we watch the Carolina locust in its flight along a dusty road, we shall have great difficulty in finding it after it alights, because the color of its wings so closely resembles that of the dust. Again, we shall have difficulty in finding bobwhite in the grass or among the weeds, no matter how carefully we follow his song, because his color blends so nicely with the surroundings. Such resemblances enable these animals to escape their enemies and are, therefore, known as *protective resemblances*. The insects are especially notable for their many examples of such resemblances.

FIG. 234. — Walking stick insect with projections on its body and legs like those on a rough branch.

An excellent instance of such a resemblance is found in the case of the katydid. In this insect the wings resemble leaves so closely in color and appearance as to deceive the most observant. In fact, all katydids have wings that resemble leaves more or less in appearance. Those insects familiarly known as walking sticks are very easily mistaken for the branches of the trees on which they live. Some have irregular outgrowths on the body and limbs which

cause them to resemble twigs still more closely. See Figure 234.

The caterpillars of certain moths known as the looping caterpillars, or measuring worms (Fig. 235), show a remarkable resemblance to the branches on which they live. They are colored like the bark and have the remarkable habit of holding fast by their false hind legs, while the long slender body projects outward like a twig.

FIG. 235.—Looping caterpillar on a branch.

Perhaps one of the most remarkable resemblances is the Kallima, or leaf butterfly, of India. Figure 236 shows the remarkable similarity of this insect to a leaf. When it alights on a branch, its wings are held vertically with the upper sides folded together so that only the under sides show. Note the dark line running through the middle of the wings like the midrib of a leaf. Note also the small projection on the end of the wing that resembles the petiole of a leaf. The legs are usually more or less hidden, and, more than that, are so colored that they are inconspicuous. The upper sides

of the wings are dark, with purple and orange markings, so that when flying, the butterfly is quite conspicuous.

Then, again, there are the small green snakes that live in the grass; the earth-colored snakes that live along the bare roadsides or in bare fields; the tree frogs that have grown to imitate the bark of the trees on which they live or, if they live among the leaves, then have grown to resemble the leaves in color.

FIG. 236. — Kallima.

A very interesting and remarkable case of protective resemblance is seen among those animals in which there is an actual change of color of their fur coats to correspond to the season. The American hare (called the white rabbit) in summer is of a cinnamon brown; but, as winter comes on, its coat turns to a white color.

Again, certain spiders that live in flowers are colored like the flowers, so that they remain hidden and lie in wait to catch their prey of unsuspecting insects that visit such flowers for nectar. Such resemblances are known as *aggressive resemblances*.

Mimicry. — In the struggle for existence, the weaker or more vulnerable animal often happens to vary in such a manner that it resembles a stronger or more aggressive

animal. This resemblance is a protection, because the weaker animal is taken by its enemies for the animal which it resembles, and consequently goes unharmed by them. The succeeding generations of the weaker animal come more and more to imitate the stronger, until, finally, we ourselves have difficulty in distinguishing one from the other. A butterfly, known as the viceroy, imitates another and larger butterfly, known as the monarch. The monarch has reddish brown wings, two inches long, with black veins. It also has a peculiar odor which is very much disliked by birds, hence it is let alone by them. Now, if another butterfly should grow to look like the monarch, even though it had no peculiar odor, it would be less liable to be eaten by birds, because the birds, having grown to know the monarch, would think that this other butterfly was also a monarch and would let it alone. Exactly this thing has happened. The viceroy has grown to resemble the monarch so closely that only a very observant person can tell them apart, and probably birds do not know one from the other, hence touch neither. See Figure 237.

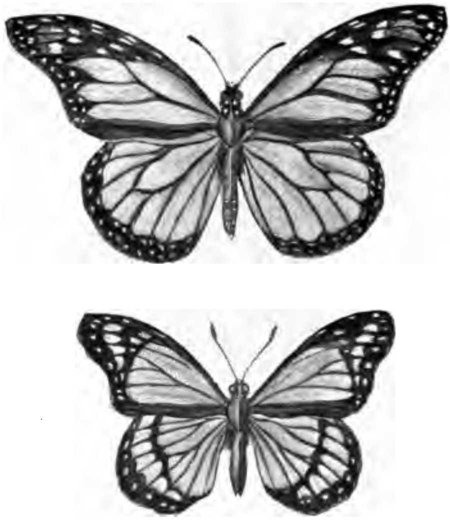

Fig. 237. — Monarch butterfly above and viceroy below. Note the resemblance.

Certain flies, known as syrphus flies, imitate bees in color, size, and general appearance so closely as to deceive experienced people.

Many examples might be given of the manner in which animals are protected from other and stronger ones. In the same way, animals are provided with means of protection against climate, scarcity of food, etc. Those animals living in cold climates are provided with thick coats of fur, feathers, or hair. Those that hibernate throughout the winter lay up during the summer a large amount of fat, to act as food when none is obtainable.

XXVIII. LIFE PROCESSES OF ANIMALS

In our study of the animal kingdom we have seen that certain processes, necessary to the life of the individual and to the perpetuation of the species, go on in the body of every animal. Since the life of the animal and the future existence of its kind depend upon these processes, they have been termed the *life processes*. Among the more important are ingestion, digestion, secretion, excretion, respiration, circulation, and reproduction.

Ingestion. — The combined activities of procuring, masticating, and swallowing food may be termed *ingestion*. Without food, the animal would soon die. Therefore, every animal is provided with some means of obtaining it and passing it to the organs of digestion. When the amœba touches a bit of food, the protoplasm of the body simply incloses the particle, for this animal has no mouth or special organs for ingesting food. The cilia of the paramecium and vorticella create currents of water that bring food into the mouth. Food is brought to the sponges by the currents of water flowing through the body. The hydra, sea anemone, and coral polyps gather food and pass it into the mouth with the tentacles. The tapeworm absorbs its food through the skin, but the earthworm swallows quantities of soil from which the food particles are extracted. Insects have biting and sucking mouth parts for obtaining their food. Fish have jaws armed with teeth, while toads collect their food with the tongue and swallow it whole. The snakes

hold their prey with their teeth, which point backward and swallow their food whole, but the birds have bills with which they pick up their food. The mammals, as a rule, possess teeth fitted either for tearing or grinding and therefore the food is usually masticated.

Digestion. — Among the most important organs in the body are those that carry on the processes of digestion. The number, size, structure, and appearance of the organs of digestion vary greatly in the different groups of animals. For example, none of the one-celled animals possess distinct organs of digestion. The food of these animals is digested anywhere in the protoplasm. In the sponges there are no distinct digestive organs, but individual cells gather and assimilate their own food. The hydra has no alimentary canal, but some of the cells of the endoderm secrete, within the body cavity, a digestive fluid that acts upon the food. The echinoderms and worms offer the first examples of animals with a fully developed digestive tract, or tube. The earthworm has a well-defined alimentary canal surrounded by the perivisceral space, or cœlome. It consists of several distinct parts and is quite similar to that of the locust. The digestive organs of the different members of the Mollusca vary in number and development, but in the clam there is a mouth, an esophagus, a stomach, and an intestine. The alimentary canal is most highly developed in the vertebrates. In the rabbit, for example, it consists of three main divisions: esophagus, stomach, and intestine. Moreover, a liver and a pancreas are present as appendages of the canal, but these are organs of secretion.

Secretion. — There are certain organs in the bodies of the higher animals known as *glands*, that take special food materials from the blood and elaborate them into products

which are useful in carrying on the work of the body. These glands are the organs of secretion and the chief ones are connected with the digestive tract and perform very important functions in the process of digestion. For example, the salivary glands opening into the mouth, where the saliva dissolves and moistens the food and, in some animals, acts upon the starch, changing it into sugar. In the walls of the stomachs of the higher mollusks and the invertebrates there are glands called *gastric follicles* that secrete the gastric juice. In the Protozoa there are no special glands for secreting digestive fluids and the whole work of digestion is accomplished by the protoplasm. The same may be said of the sponges and hydræ except that in the latter certain cells of the endoderm secrete a digestive fluid. The liver and pancreas are two very important organs of secretion connected with the alimentary canal of many animals. The liver of vertebrates is the largest gland in the body. It secretes bile, the work of which is imperfectly understood, but it certainly performs an important function in digestion.

Excretion. — There are two antagonistic processes going on in the bodies of all animals during life; namely, a building-up process and a tearing-down process. In the tearing-down process, waste materials are given off into the fluids of the body — blood in those animals that have blood. These waste materials, which consist mainly of carbonic acid, water, and urea, must be thrown off from the body, or excreted. In the vertebrates, they are thrown off by the lungs, skin, and kidneys. In the lower animals, we do not find all of these special organs of excretion. For example, the amœba excretes carbonic acid through the surface of the body and the pulsating vacuole aids in excret-

ing other substances. In the sponges the cells lining the canals give up their products of excretion to the water and are thereby carried out of the body. Excretion is carried on through the surface of the body wall in the hydra. In the starfish there is a system of tubes containing a fluid (mostly water) that probably acts as an excretory apparatus. Moreover, the respiratory cæca act as organs of excretion. In the earthworm the nephridia and skin get rid of the waste materials, while the tracheæ and malpighian vessels are the excretory organs in insects. The nephridia of worms and the malpighian vessels of insects are comparable, in their work, to the kidneys of vertebrates. Respiration is a method of excretion and an exceedingly important life process. If it is completely arrested, death ensues. It is carried on very differently by different animals, as has been shown. Respiration is most highly developed and effectually carried on in those animals that breathe by lungs, especially the birds and the mammals.

Circulation. — The food that an animal eats and digests must be distributed throughout the body in order that the different organs may obtain nutriment for building up worn-out tissues and for the development of energy to accomplish work. Moreover, the waste material produced in all parts of the body must be brought to the lungs, skin, kidneys, and other excretory organs to be thrown off. In the higher animals the food is distributed and the waste matter brought to the excretory organs by a fluid (blood) circulating through a system of tubes. The whole process is known as *circulation*. There is no definite system of blood vessels among the lower animals until the echinoderms are reached. In the Protozoa, the food circulates through the endosarc. The currents of water distribute the food to the different

parts of the sponge's body, while in the bodies of the hydræ, sea anemones, and polyps the food circulates in the fluid of the body cavity. But in the jellyfishes there is a system of tubes (not blood vessels) branching off from the stomach, as we have seen, through which the food is carried directly to the various parts of the body. The first approach to a true circulatory system is made by the starfish and sea urchins. The earthworm possesses a better defined circulatory system but has no true heart. Many members of the Arthropoda and Mollusca present a well-defined circulation, but it is among the vertebrates, especially birds and mammals, that we find the highest types of circulation.

Reproduction. — To insure its existence and to prevent its extinction every species of animal is endowed with the power to reproduce itself. There are two methods of reproduction among animals; namely, *asexual* and *sexual*. Only the lower animals reproduce asexually. The great majority of animals, if not all, reproduce sexually. There are also two methods of asexual reproduction; namely, *fission* and *budding*. In asexual reproduction by fission the animal simply divides in two parts. Fission takes place in the Protozoa, in some cœlenterates, and in some worms. In asexual reproduction by budding, a budlike protuberance forms on the side of the body of the parent animal. The bud grows and gradually develops into a mature form which may or may not remain attached to the parent animal. Reproduction by budding takes place among the sponges, Cœlenterata, some worms, and ascidians.

The most universal and important method of reproduction among animals is the sexual method, which consists in the union of two cells, the sperm (male) cell and the egg (female) cell. Among the vertebrates, in most arthropods

and echinoderms, and in some mollusks and worms these cells emanate from two different individuals, male and female. Both kinds of cells may be produced by the same individual. For example, each earthworm produces both the sperm cell and egg cell. Hydræ, sea anemones, jelly-fish, and many worms are bisexual; that is, produce both the sperm cell and egg cell. After the sperm cell unites with, or fertilizes the egg cell, development of the embryo begins. The process of growth has been described in Chapter III.

XXIX. THE GEOGRAPHICAL DISTRIBUTION OF ANIMALS

Geographical distribution. — We visit menageries with the keenest interest to see strange animals from strange countries. It is evident from a moment's thought that different countries are the homes of very different animals. For example, the lion is found in Africa, the kangaroo in Australia, the boa constrictor in South America, and so on through a long list of examples that might be cited. In North America we find the coyote, the black bear, and the rattlesnake; but we do not find them in Europe. In the United States, we find the grizzly bear in the Rocky Mountains, but not in New England, or the southern states. Again, the alligator is found in the swamps of the Gulf states and nowhere else in the United States. Thus we see that some animals, at least, live in certain well-defined areas of the earth's surface, and it is easy to make a map, showing the areas of the country in which many animals are found.

When the extent and location of the areas, or regions, occupied by an animal have been ascertained, the geographical distribution of that animal may be said to have been determined.

Questions arising from the distribution of animals. — Animals vary greatly in their ability to go from one place to another. For example, a wild goose can go from Canada to Florida much easier than a pond snail. There are also

barriers that prevent animals from going from one region to another. Finally, after an animal has reached a region far from its original home, it is liable to become profoundly changed in habits, character, and, possibly, in structure.

Why is it that certain animals occupy certain areas? How do they pass from one region to another? What retains animals within the boundaries of certain areas? How are animals modified when they migrate to new areas? These are some of the questions that arise from the study of the distribution of animals.

Means of dispersal. — One of the most universal means by which animals are distributed from one region to another is through the agency of man. For example, the eel has been put into many ponds and streams of the United States that it could not have reached except by the aid of man. The horn fly, a serious pest to cattle, was brought over from Europe, probably in ships with live stock. By the same agency, the English sparrow and even the horse have been brought to America.

Birds can fly from one region to another, across wide expanses of water or over high mountain ranges. Fish can swim to widely remote parts of the sea. Many mammals can swim across narrow seas, rivers, etc. Some mammals, notably the whales and the seals, can swim for leagues at sea. Mammals are sometimes carried on floating masses of vegetation to islands in the sea. Birds are blown across seas by high winds. The bodies of some animals, as rotifers and infusorians, may become so dry and light that they are carried by winds. Insects are often carried on birds' feet, blown by the wind, or floated on the water in logs of wood, etc. Worms crawl, frogs and toads leap, snakes swim and crawl.

Barriers to dispersal. — The barriers that prevent or retard the migration of animals from one region to another may be roughly classed as land, water, and climatic barriers. Of course, land is a barrier in the strictest sense only to those animals that live in the water. For example, it is easy to see that a fish on the coast of California would be forever debarred from entering the Gulf of Mexico by the Isthmus of Panama, narrow though it be. Likewise, fish living in inland seas without outlets are forever debarred from leaving them of their own free will. In two rivers running side by side, and emptying into the ocean, there may be fish that will never get from one to the other, owing to the narrow strip of land between.

Deserts are barriers to the dispersal of many animals. It is true that this is due to the absence of water more than to any other cause, yet they are land barriers.

Falls in streams are barriers to the distribution of fish. For example, eels could never have reached the Great Lakes over Niagara Falls, unless they had been aided by man. Mountains present strong hindrances to the migration of animals. Especially is this true of ranges that are capped with snow. The mammals of California differ in some species from those on the eastern side of the Rockies.

Perhaps, on the whole, water is a more serious barrier to a greater number of animals than any other barrier noted. The ocean is a barrier to many birds; and birds are probably best fitted for migration of any animals in existence. A small river will hold a race of monkeys in confinement in a given area. Many animals, however, can swim across wide streams. The effect of water as a barrier is well shown by a study of the animals on an island separated from the mainland by a deep channel. The island of Madagascar is

a noted case. This island is separated from the mainland by a channel of water about two hundred and thirty miles in width. On this island nearly all of the species of animals are different from those in Africa. Moreover, the species of birds differ from those only two hundred and thirty miles away.

Salt water is a firm barrier to fresh-water animals. Thus the fresh-water animals living on an island not two hundred yards from the continent would be effectually debarred from swimming to that continent. On the other hand, there are many fish living in salt water that are debarred from entering fresh-water lakes.

The third great class of barriers may be called climatic, which will include the effects of temperature, moisture, and dryness.

There is a great difference between the animals of the tropics and those of the arctic regions. A leopard with its short hair would never venture into the arctic region. On the other hand, a polar bear would be exceedingly uncomfortable in India. The parrots of Brazil would die in Canada. The sloths, ant-eaters, and monkeys of the tropics would not survive in the north. Neither would the foxes, sables, and minks of Canada be able to live long in Central America.

As to the effects of moisture and dryness recall the toad. On account of excessive evaporation from its skin it demands a moist atmosphere and could not survive on the deserts of the Southwest. On the other hand, the Gila monster would find it extremely distasteful to live in the valley of the Mississippi.

Notwithstanding all these barriers to the distribution of animals, every species is unconsciously forced to spread over larger areas or pass out of existence. For, in time, a species

becomes too abundant in a certain area and those on the outskirts venture farther and farther in search of food. Often a species is driven out by enemies, change of climate, etc. In such cases, it may pass over barriers that heretofore seemed impassable.

Fauna. — Briefly speaking, the fauna of a region consists of all the animals naturally found in that region. For example, the fauna of New York or Mississippi would be all the animals found in each respective state. The faunæ of two adjoining states are usually very much alike, because the conditions are about the same, and, usually, there are no great barriers between. On the other hand, the faunæ of two widely separated states like New York and Mississippi are considerably unlike. This is due largely to the difference in climate.

Faunal areas. — A faunal area is, of course, the area or region occupied by a certain fauna. For example, we may consider the state of Colorado with its fauna as a faunal area. It has been shown above that the relation of faunal areas to each other depends first upon their proximity. Secondly, it will depend upon the barriers between these faunal areas. For example, the fauna of the Island of Madagascar differs greatly from that of Africa, because of the water barrier between. The fauna of California differs much from that of the states separated from it by the mountains.

In traveling from the Atlantic to the Pacific, across the United States, three fairly distinct regions as regards the fauna will be noticed. The moist, temperate region along the Atlantic and in the Mississippi Valley, with its characteristic animals, constitutes the first region. Then, as we reach the high plateaus of the Rockies, dry and treeless,

we shall find that the animals of the Atlantic region have been replaced by forms quite different. Finally, after climbing the Sierra Nevada, and descending into the Pacific region, another assemblage of animals differing from either of the above — but not so markedly from the second — will be found. It must be borne in mind, however, that there is no distinct dividing line between these faunal areas. The first overlaps the second, the second the third, and *vice versa.*

The North American continent as a whole, exclusive of the circumpolar region which is common to Asia and Europe, may be divided into three primary faunal areas. Beginning at the North Polar sea these are as follows: the Boreal Region, the Austral Region, and the Tropical Region. Here again the areas are not sharply defined, for the adjacent ones overlap each other and animals common to one are found in the other.

Faunal areas of the earth. — The earth, as a whole, has been divided into seven — some authorities make eight — great areas. These are the *Arctic,* the *North Temperate,* the *South American,* the *Indo-African,* the *Madagascar,* the *Patagonian,* and the *Australian.* The differences between the faunæ of these various areas are due to the climate and the barriers between them.

The manner in which the distribution of animals has affected species. — It has already been shown that there is a tremendous struggle going on between animals all the time. By this struggle, many are killed, and many are driven out of certain regions to seek other regions where competition is not so great. Thus there is a constant tendency among animals to distribute themselves over the earth in search of conditions more favorable to their existence.

As a result of this intense struggle, an animal may be crowded across a barrier into a region entirely new to it, where the conditions are so extremely favorable for its growth and increase that it may become strong enough and numerous enough to actually drive out or kill another closely allied species existing in that region. For example, the black rat was introduced into America from Europe about 1544. The conditions here were so favorable that it increased in such numbers as to aid very materially in crowding out and annihilating our species of native rats. Later, in 1775, the brown rat was brought over to America. It, in turn, throve prodigiously, and practically exterminated the black rat, but remains as our common pest of barns and outbuildings. *Hence one result of the distribution of animals is the extermination of species.*

Another result of the distribution of animals may take place that will be exactly the opposite of the one just described. Suppose a short-haired, semi-tropical animal living in Mexico should be forced by degrees northward into Canada. One must bear in mind that this forced migration must be very slow and must extend over a long period of time. It is conceivable that, as this species went northward, the hair of the individuals of successive generations would gradually grow longer and longer to adapt them to the changed conditions of the climate. By the time the animal reached Canada it might be so changed in regard to its hair and organs of the body as to have become a distinct species. In other words, when an animal is forced across a barrier into a new region, the process of adaptation to surroundings and of natural selection may produce an entirely new species. Hence a second result of the distribution of animals is the *formation of new species.*

Other significant features of the distribution of animals. — A knowledge of the distribution of animals aids us very much in determining the history of the earth. For example, if we find a species of animal "having few or no facilities for dispersal," on both sides of a very important barrier, we feel pretty sure that there was a time in the history of the earth when that particular barrier did not exist. Because, if it had always been in existence, the species of animal mentioned would not be found on both sides, since the animal could not pass over the barrier. Hence a knowledge of the distribution of animals often leads to the disclosure of very profound changes in the topography of the earth's surface. To illustrate, take one of the fresh-water crayfishes of Great Britain. The same species is found on the continent of Europe. Now, since this crayfish cannot pass across the salt water barrier of the English channel, it would seem to indicate that this barrier did not exist at some former time. In such a case, Great Britain would have been simply a part of Europe. As a matter of fact, such is the case, as has been proved by other and conclusive evidence.

XXX. THE HISTORY OF THE SCIENCE OF ZOÖLOGY

THE study of animal life began long before the Christian Era. The Greeks, especially Aristotle, acquired a wide range of knowledge concerning a great variety of animals; but this knowledge consisted of a mass of isolated and unconnected facts that led to no systematic outline of the animal kingdom. As a well-grounded science, zoölogy has not existed much over two hundred years, although the information concerning animals and animal life gained prior to that time included valuable and reliable facts concerning a wide range of forms.

Aristotle. — Aristotle (384–322 B.C.), the eminent Greek philosopher, by his own researches and observations, gathered together an immense array of facts regarding animals, some of which were remarkably accurate and some of which were curiously incorrect. He wrote several treatises on zoölogical subjects among which are *The History of Animals, The Generation of Animals*, and *The Parts of Animals*. He divided the animal kingdom into two great groups; namely, one containing those forms that possessed blood and another including the forms without blood.

Pliny. — After Aristotle came Pliny, the elder, who lived in the first century and wrote a natural history which dealt with the whole realm of nature — plants, animals, minerals, stars, etc. He cannot be regarded as an original worker

but rather as a compiler of facts, amid some fables, the former borrowed largely from Aristotle. After Pliny's time the sciences declined and up to the sixteenth century, with few exceptions, no contributions of note were made to the science of zoölogy.

Sixteenth century. — During the sixteenth century there came a revival of the study of animals instituted chiefly by the interest in the anatomy of the human body. During this period, Conrad Gesner published (1551–1558) his *Historia Animalium,* a work of forty-five hundred folio pages, in which he recognized four groups of animals: viviparous quadrupeds, oviparous quadrupeds, birds, aquatic animals and serpents. Fabulous monsters were yet believed in, for he illustrated winged dragons, many-headed hydræ, and crowned basilisks.

Seventeenth century. —In this century came a man whose name will be inseparably linked with zoölogy for all time. This was William Harvey who, in 1616, discovered and demonstrated the circulation of blood. The discovery of this truth must be accorded one of the greatest scientific events of all time. Moreover, Harvey studied the embryology and development of the chick and his contributions to this phase of zoölogy are exceedingly important. Again, in his famous phrase "*omne vivum ex ovo,*" he enunciated the principle that all living things arise from an ovum.

During the period from 1590–1600 Hans and Zacharias Janssen invented the compound microscope and, later, in the seventeenth century, it was perfected so as to aid very greatly in the study of animal structure and embryology. Malpighi first studied the development of the chick with the microscope, discovered and described certain organs of insects — malpighian vessels — with which his name is still

connected, and made other histological contributions to zoölogy. Leeuwenhoek, a Dutch investigator, discovered blood corpuscles and striated muscle fibers, watched the circulation of blood in the tail of a tadpole, thus confirming Harvey's discovery, and described many forms of Protozoa, rotifers, and hydræ hitherto unknown. Swammerdam, another Dutchman, is known to all entomologists, for he studied and described the habits, metamorphoses, and anatomy of many different insects, accompanying his descriptions with illustrations. Just here must be mentioned the two Englishmen, Hood and Grew, who discovered, in the tissues of plants, minute cavities filled with fluid and surrounded by walls which they termed *cells*.

Passing over other and lesser investigators we come to the English clergyman, John Ray, who first systematized the zoölogical knowledge already gained and put the science of zoölogy on an organized basis. He grasped the idea of species and saw the real value of a comparison of anatomical characters of animals to show their true relationships, which enabled him to classify animals much better than they had been heretofore.

Eighteenth century. — The year 1707 saw ushered into the world the Swedish founder of modern systematic zoölogy, Carl Linne, or Linnæus. He first established the value of groups higher than species — genera, orders, and classes — and used them in their proper relation to each other. He also instituted the system of naming animals according to the principles of the binomial nomenclature. That is, each animal was given two names taken from the Latin language, the first name indicating the genus and the second name the species to which the animal belonged. Linnæus also named and described each species of animal and

plant with which he came in contact and published all of his observations and principles in a work entitled *Systema Naturæ*, of which thirteen editions have been published. "By universal consent the Systema Naturæ is taken as a starting point by systematists." The names of Bonnet, Heller, and Hunter were prominent in zoölogy in the eighteenth century. As a naturalist, the name of Gilbert White stands preëminent, and his book, *Natural History and Antiquities of Selborne*, is a classic both in science and letters. However, the remaining name to which we must give more than passing notice is that of Buffon. Buffon was essentially a philosophical zoölogist and was the first of the great evolutionists. At this time it was held and, in fact, could not with personal safety be disputed, that all the different species of animals were immutable, or unchangeable, and that each was created just as it then appeared. On the other hand, Buffon promulgated the idea of the mutability of species. He held that species of animals did not forever remain stable and fixed, but that they gradually changed from one form to another so that new species were continually being developed from existing ones. In other words, he believed in the principle of evolution, although he was not the first to announce such a doctrine.

Transition from the eighteenth to the nineteenth century. — Buffon was followed (1774–1829) by Lamarck, a Frenchman, who held the same views in regard to the mutability of species although he ascribed different causes for the changes that produced new forms. Lamarck held that there was a unity [1] in the animal kingdom and that all

[1] According to the prevailing conception of his time, Lamarck held the view that the animal kingdom presented a serial arrangement, which differs markedly from the modern view.

the different forms had developed by slow but gradual changes from the lowest, or primitive form. In their general views, Buffon and Lamarck were supported by another eminent French zoölogist, Geoffrey St. Hilaire. But the views of these three men exerted little influence during their time, owing to the work and writings of Georges Cuvier. Cuvier (1769–1832) was a great zoölogist and completely dominated the science of zoölogy for half a century, especially in France, where he lived and taught. He was a profound student of the anatomy of animals and formed a classification of animals founded upon their comparative structures. He rejected the idea of the unity of the animal kingdom and held that there were four distinct and independent types of animals, not connected with each other by intermediate forms, living or fossil.

Nineteenth century. — In 1838 Schleiden enunciated the cell theory for plants according to which all parts of the body are built up either of cells or of tissues derived from cells. Closely following him, Schwann propounded the same theory for the animal body. In 1827 Von Baer discovered the ovum of mammals, and later, from 1843 to 1846, Barry established the relation of the male reproductive cell (sperm) to that of the female reproductive cell (ovum) by actually observing the union of the two, thereby determining the meaning of fertilization.

In the early part of the last half of the century — 1859 — occurred what may fairly be called the most important event in the history of biological science, the publication of Charles Darwin's *Origin of Species*. Up to this time the ideas of evolution advanced by Buffon, Lamarck, St. Hilaire, and Erasmus Darwin had not received general recognition among zoölogists, to say nothing of the great mass of teachers,

writers, and scholars. But with the *Origin of Species* began a storm of discussion and debate out of which there has arisen a calm and sane acceptance of the gradual development of the various forms of plant and animal life by a process of evolution. Darwin gathered such a mass of facts and marshaled his proofs in such a clear, logical manner that the world could not deny the force of his arguments or escape the convincing power of his conclusions.

From 1850 to the present time, the contributions to the science of zoölogy have been steadily increasing in number and value and very great additions have been made to our knowledge of the subject. The perfecting of the compound microscope, together with the modern methods of research, has given a profound insight into the structure of the animal body, disclosed much concerning the functions of the various organs, revealed the process and something of the significance of reproduction, and added vastly to our knowledge of animal life.

For a fuller knowledge of the history of zoölogy, one should become acquainted with the life work of Wotton, of Vesal, Treviranus, Goethe, Wolff, Von Baer, Siebold, Erasmus Darwin, A. R. Wallace, Agassiz, Owen, Haeckel, Huxley, Weismann, and others.

INDEX

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